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SURFACE-DUCT SONAR MEASUREMENTS (SUDS I - 1972) PROPAGATION LOS--ETC(U)
APR 76 E R ANDERSON

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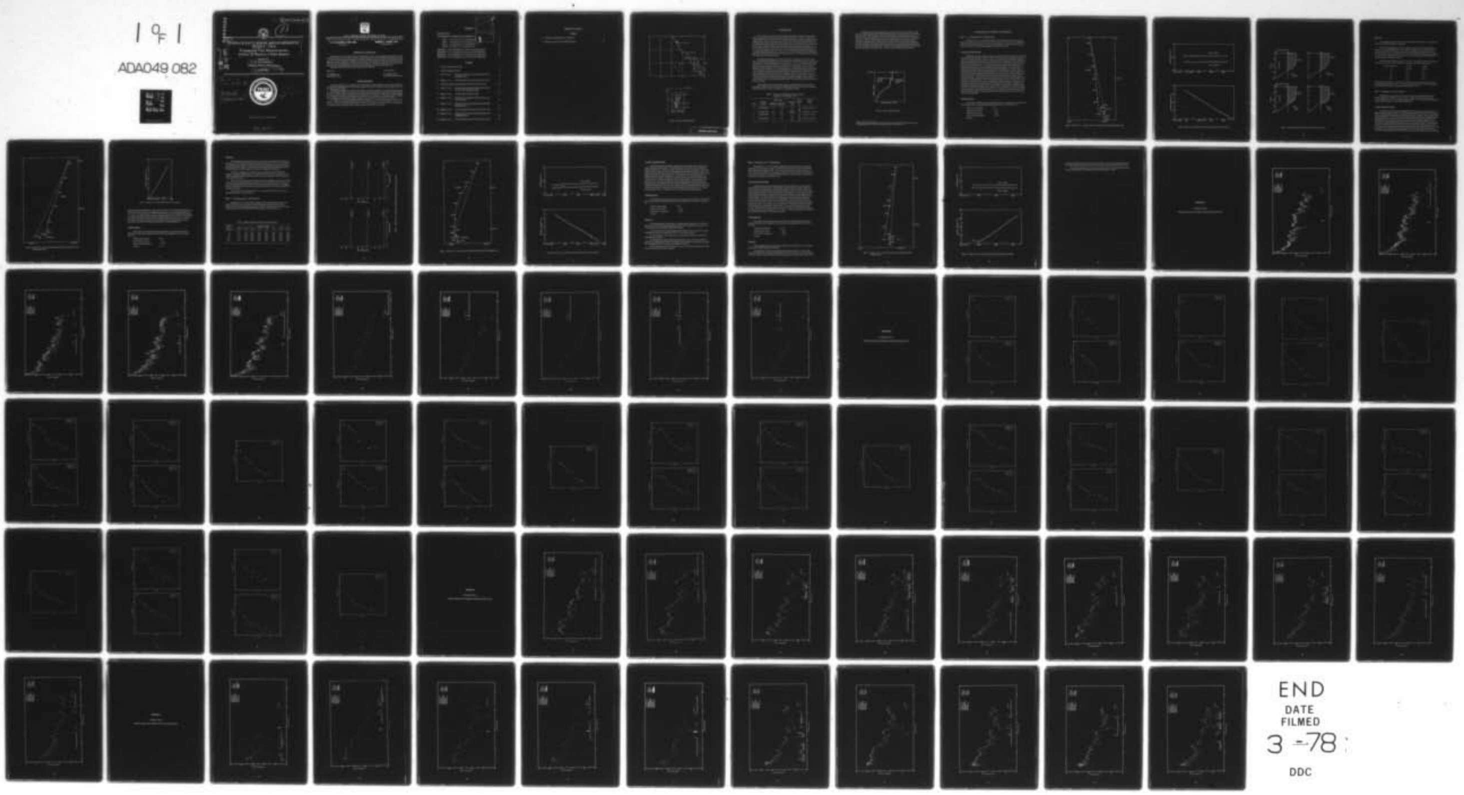

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SURFACE-DUCT SONAR MEASUREMENTS (SUDS I - 1972)
Propagation Loss Measurements. Volume V. Station 4 Data Report.

edited by
(10) E. R. Anderson
Undersea Sciences Department

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

R. B. GILCHRIST, CAPT, USN
Commander

HOWARD L. BLOOD, PhD
Technical Director

ADMINISTRATIVE INFORMATION

During February 1972 the Naval Undersea Center conducted a series of 18 propagation loss experiments in three deep-water areas off the coast of California. These experiments are known as the SUrface Duct Sonar Measurements (SUDS I – 1972). This work was originally supported by the then Naval Ships Systems Command, Sonar Technology Division, PMS-302-4 and partly supported by the Office of Naval Research, code 102-OSC. The preparation of this report began in April 1973 under the sponsorship of the Naval Sea Systems Command, code 06H1-4, problem SF 52-552-602, task 19344. This report covers work from March 1971 to February 1976 and was approved for publication in April 1976.

Technical reviewers for this report were M. A. Pedersen and R. F. Hosmer.

Released by

H. E. MORRIS, Head
Ocean Sciences Group

Under authority of

B. A. POWELL, Head
Undersea Sciences Department

ACKNOWLEDGEMENTS

The SUDS I program was a coordinated and cooperative effort involving personnel from the Undersea Sciences and the Undersea Surveillance Departments. The program was basically an Acoustic Propagation Division project developed by H. P. Bucker and H. S. Aurand.

The Principal Investigator was J. Cummins. H.P. Bucker was the Senior Scientist for the CW-pulse measurements and D. L. Keir the Senior Scientist for the explosive measurements. Additional contributions were made to experiment planning by J. R. Lovett and J. D. Pugh. Preliminary analysis of acoustical data was done by H. P. Bucker and H. E. Morris. Assisting in the preliminary data reduction and analysis of the acoustic data was J. L. Thompson, an exchange scientist from RANRL, Sidney, Australia, and R. W. Townsen. Preliminary analysis of the environmental data was done by K. W. Nelson.

H. P. Bucker was the Scientist-in-Charge aboard the *DeSteiguer*, D. G. Good was Scientist-in-Charge aboard the *Lee*, and P. A. Hanson was Scientist-in-Charge aboard the *Cape*. Assisting with the acoustic measurements at sea were: T. E. Stixrud, C. R. Lisle, N. J. Martini, D. White, and R. F. Hosmer. The assistance of the officers and men of the *DeSteiguer*, *Lee*, and *Cape* in making the propagation loss measurements program successful is acknowledged.

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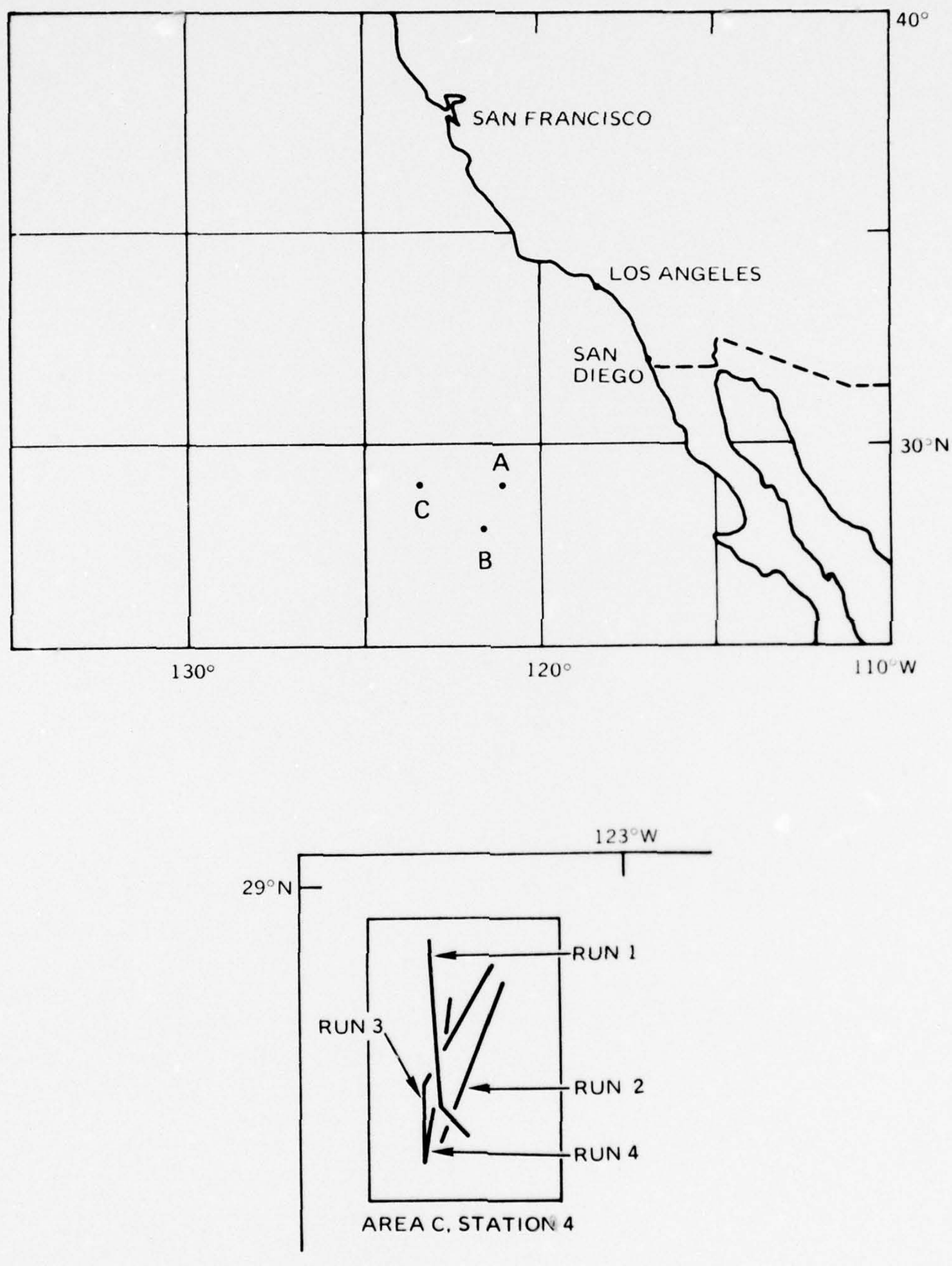


Figure 1. Location of experimental areas.

INTRODUCTION

This the fifth in a series of five volumes describing the near-surface acoustic propagation loss measurements made during the SUDS I experiments. Volume 1 describes the experimental procedures, discusses the instrumentation used in making the propagation loss measurements, and the data reduction procedures. This volume (V) is a detailed report of the propagation loss measurements made during station 4, during which four acoustic experiments were completed. Figure 1 shows the track of the source ship during these runs. Source ship's speed was 3 knots during all runs. CW pulsed sources were employed on runs 1, 3, and 4 and explosive sources on run 2. Table 1 summarizes information pertinent to the individual propagation loss runs. Listed for each run are the beginning and ending dates and times, minimum and maximum range between the source and receiver ships, frequencies used, and source and receiver depths.

The detailed propagation loss data are contained in Appendices A-D. These appendices contain plots of propagation loss as a function of acoustic range for each frequency and receiver depth. CW pulsed sources were used on runs 1, 3, and 4. The plots are the propagation loss for each received CW pulse as a function of acoustic range. At the bottom of each plot, remarks pertinent to that plot are indicated. The maximum acoustic range is indicated by the vertical arrow (↓) and individual noise level determinations by the symbol (∿). In addition, arrivals missing because of down periods when the recorder paper was being changed, periods when a source was inoperative, and periods when the arrivals, or most of the arrivals, were below noise level are shown. Run 2 was an explosive source run. On these plots the noise-limited measurements are plotted as triangles. These measurements represent minimum possible propagation losses. Non-noise-limited measurements are plotted as squares.

The remainder of this report discusses, for each propagation loss run, the average sound-speed profiles, average values for the AMOS parameters, and the major propagation loss features based on visual comparisons of propagation loss plots.

Table 1. Summary of Propagation-Loss Experiments
Station 4, 21-23 February 1972

Run	Date/time (LST)	Range, kyd Minimum	Range, kyd Maximum	Frequency, kHz	Source depth, m	Receiver depth, m
1	21/2342-0646	0.1	33.3	3.5	43	6/36/73/118/181
				5.0	46	
2	22/1210-1705	0.1	33.1	explosive	18	6/36/72/117/181/38
3	22/1810-0104	2.3	35.1	1.5	43	6/36/72/117/180
				2.5	43	
4	23/0116-0632	2.6	33.4	1.5	43	6/36/72/117/180
				2.5	43	

The AMOS near-surface propagation loss prediction model requires single average values of isothermal layer depth, depressed channel depth, sea state, and sea surface temperature as inputs*. The isothermal layer depth is defined as the depth below the surface at which the temperature gradient from the surface is greater than –0.3° F/100 ft. Because of the effect of pressure, this results in a surface sound channel. The depressed channel is formed by an isothermal layer within the water column. This latter vertical temperature structure results in a sound-speed minimum near the top of the isothermal layer because of the effect of pressure on sound speed. The width of the depressed channel is approximately equal to the depth of the channel axis*. Figure 2 aids in defining these parameters.

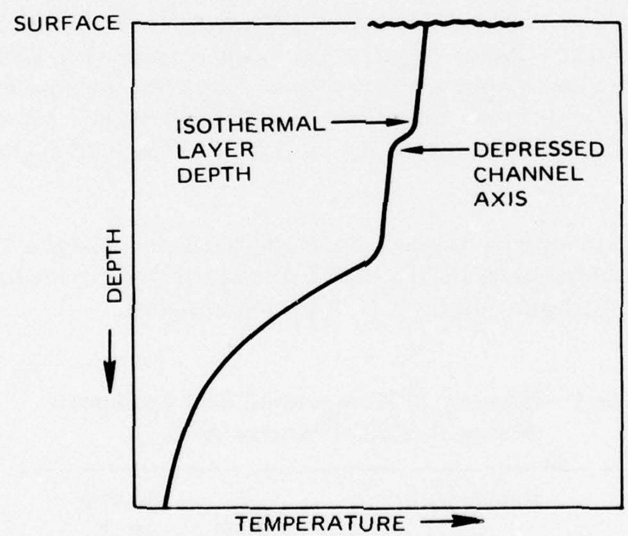


Figure 2. Vertical temperature profile.

Underwater Sound Laboratory Report 255A, Report on the Status of Project AMOS (Acoustic, Meteorological, and Oceanographic Survey), *by H. W. Marsh and M. Shulkin, March 1955 (revised May 1967).*

ENVIRONMENTAL SUMMARY AND COMMENTS

RUN 1 21-22 February 1972, 2342-0647 LST

During this run 3.5- and 5.0-kHz propagation losses were measured over acoustic ranges from 100 yd to 33.3 kyd. Figure 3 shows the track of the source and receiving ships and the 2342 LST propagation path. Figure 4 contains plots of source level and acoustic range, derived from 11 travel-time measurements, versus time of day.

Average Sound-Speed Profile

Individual sound-speed profiles suggested a sound-speed profile boundary was crossed between 0100 and 0300 LST. However, a plot of sound-speed profiles taken at 10-min intervals between 0100 and 0300 LST did not support the crossing of any definitive boundary. The individual profiles showed transient surface channels to varying depths and intermittent small depressed channels. Figure 5 contains a plot of these average data. Also shown are the source and receiver depths. The average sound-speed profile is characterized by a 17-m surface channel underlain by a small negative sound-speed gradient to a depth of 80 m. During this experiment the source ship reported 5- to 6-knot winds, 1-ft waves, and 8- to 10-ft swell, while the receiver ship reported light airs to 5-knot winds, calm to ripples, and 4-ft swell. Sea-surface roughness measurements were obtained by the Waverider buoy from 2342 to 0647 LST. Spectral analysis of these measurements indicated a change in the spectrum with time. During the first hour of the run most of the sea-surface roughness was centered at a wave period of 11.8 sec, with secondary peaks at 10.5, 9.0, and 7.8 sec. The spectrum from 0042 to 0241 LST showed that the sea-surface roughness, centered at 11.8 sec, had decreased from the roughness present during the previous hour. In addition, the secondary swell peaks decayed and were not detectable. The spectrum from 0242 to 0641 LST showed most of the roughness still centered at 11.8 sec. However, a new train of swell moved into the area with a peak centered at 14.7 sec. Receiver 1 was located in the surface channel, receivers 2 and 3 in the small negative sound-speed gradient layer, and receivers 4 and 5 in the thermocline.

AMOS Parameters

The number of observations and the average values of these parameters, derived from the thermistor chain measurements and applicable to the run 1 experiments, are:

number of observations	2421
isothermal layer depth	92 ft
depressed channel axis	167 ft
surface water temperature	59.7°F
sea state	1

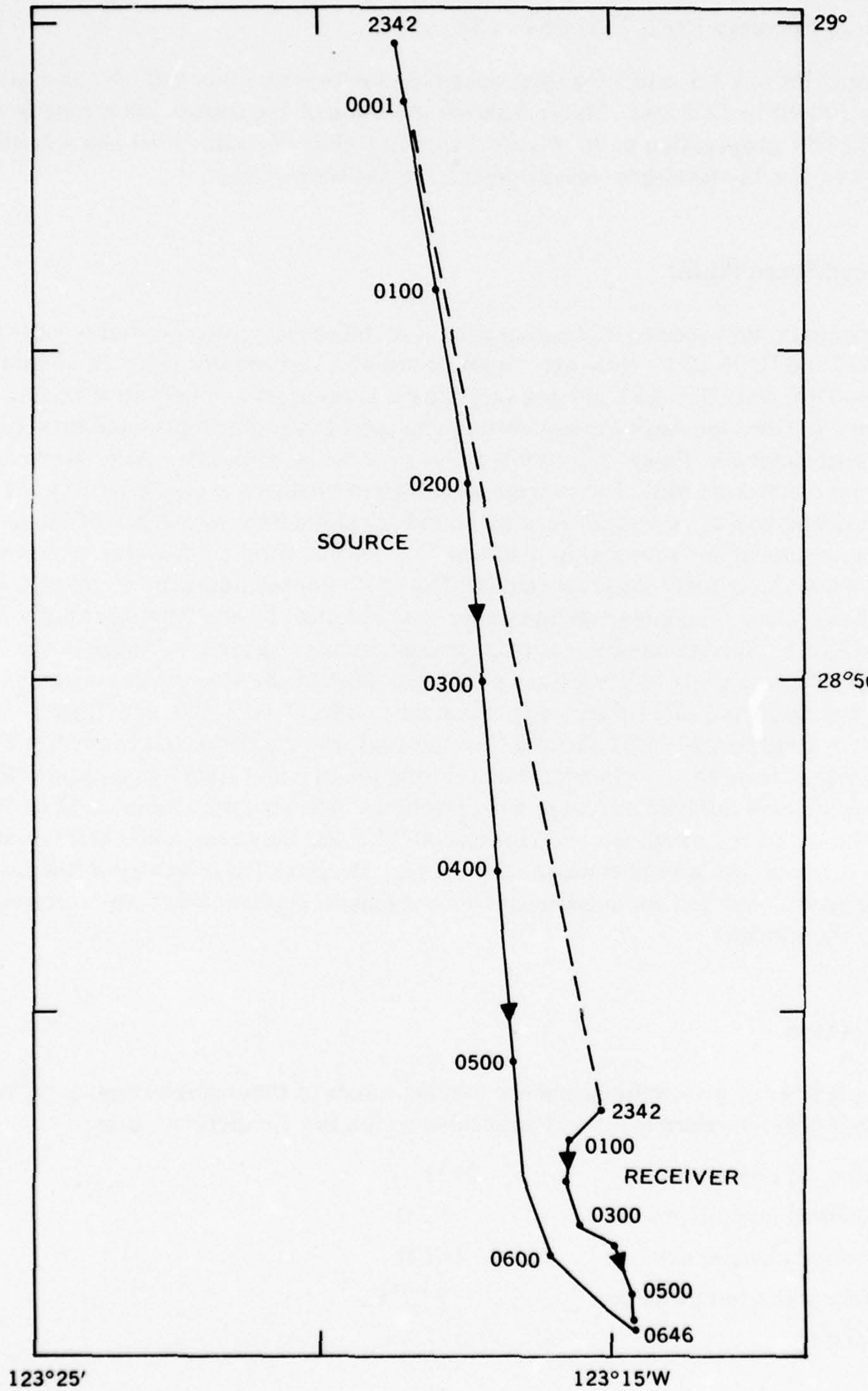
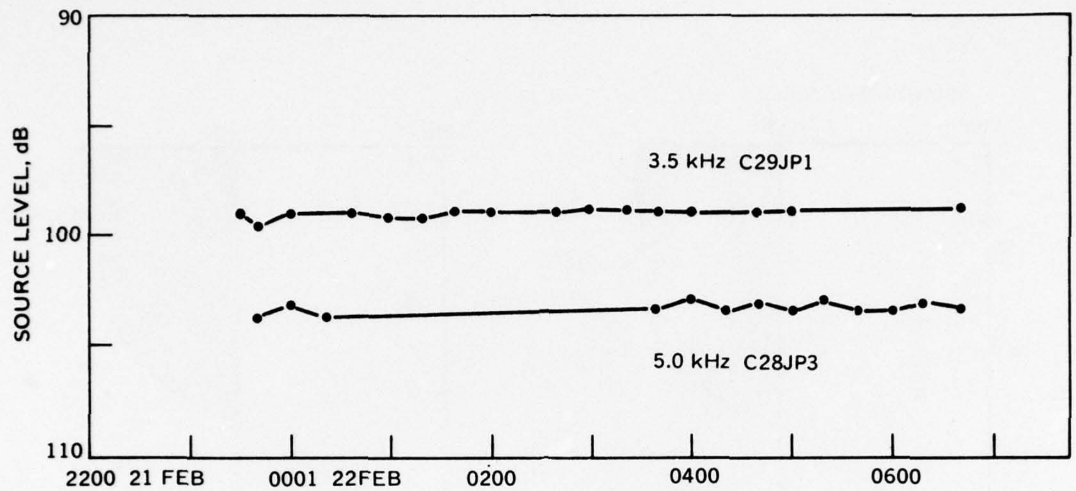


Figure 3. Station 4, run 1. Tracks of source and receiver ships and 2342 LST propagation path.



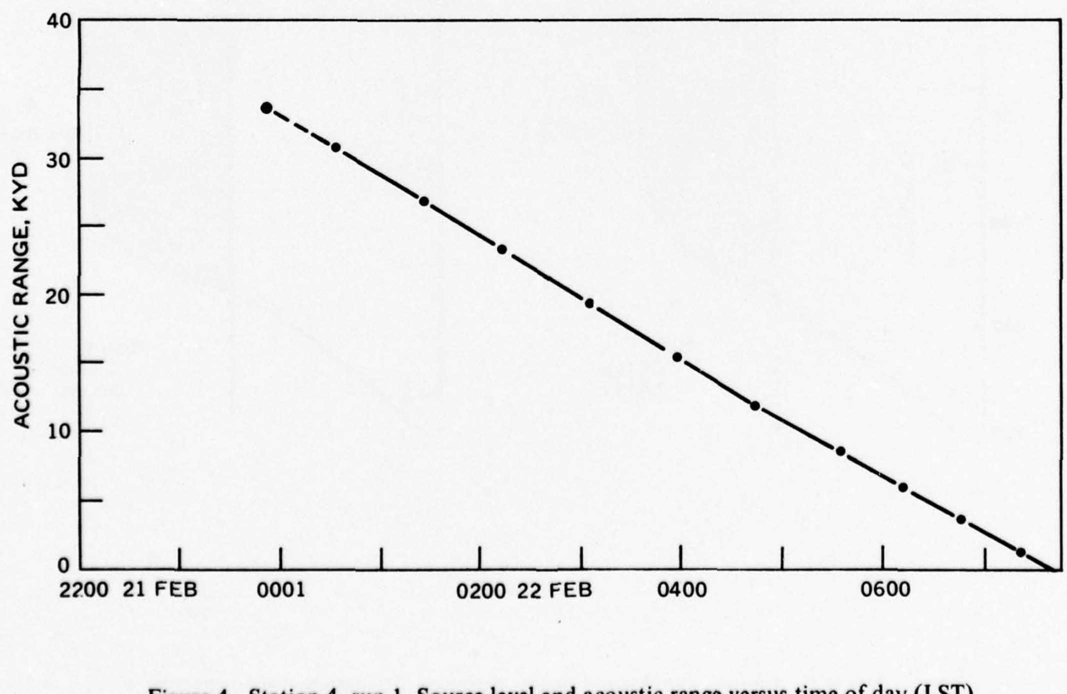


Figure 4. Station 4, run 1. Source level and acoustic range versus time of day (LST).

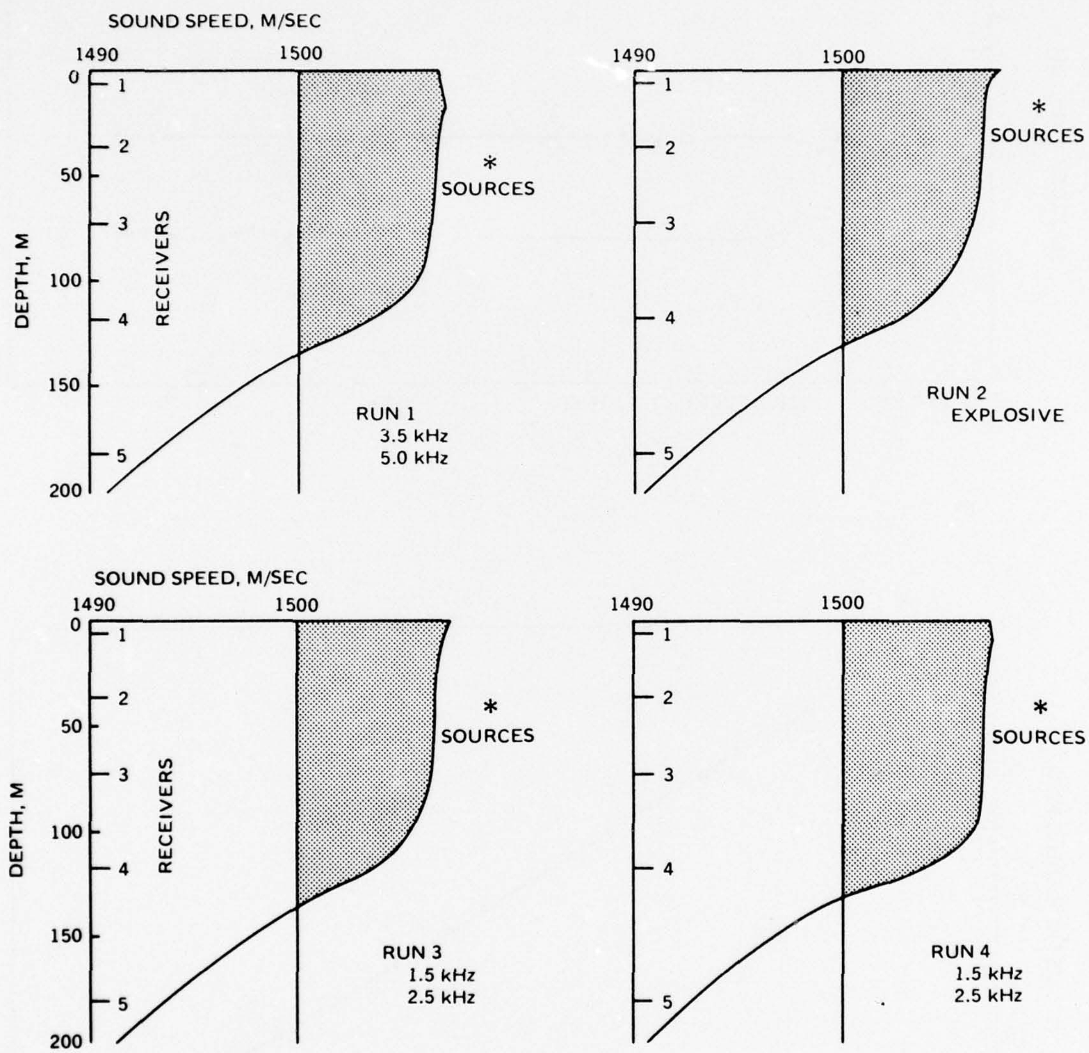


Figure 5. Average sound-speed profile summary for station 4 acoustic runs.

Discussion

The propagation loss measurements are summarized in Appendix A. A visual comparison of these plots suggests the following:

- The 5.0-kHz propagation losses recorded on all receivers were slightly greater than the 3.5-kHz propagation losses. The 3.5-kHz propagation loss recorded on the 6-m receiver, located in the 17-m surface sound channel, was slightly, but not markedly, less than that recorded on the four deep receivers. At 5.0 kHz the propagation loss recorded on the 6-m receiver at ranges greater than about 20 kyd was a nominal 10 dB less than that recorded on the four deepest receivers.

- The maximum range for run 1 was 33.3 kyd. At both frequencies the maximum range was not recorded on any hydrophone. The maximum ranges recorded were:

Receiver Depth, m	3.5 kHz	5.0 kHz
6	32.1 kyd	33.2 kyd
36	33.2	32.7
73	31.6	32.3
118	31.2	32.6
181	32.3	31.9

For the three deep receivers, many of the 3.5-kHz arrivals were below the noise level for ranges greater than about 21 kyd. For the two deep receivers many of the 5.0-kHz arrivals were below the noise level for ranges greater than about 26 kyd.

RUN 2 22 February 1972, 1210-1705 LST

During this run, explosive sources were used to measure propagation losses over acoustic ranges from 100 yd to 33.1 kyd. Figure 6 shows the track of the source and receiver ships and the 1705 LST propagation path. Figure 7 is an acoustic range versus time-of-day plot derived from 12 travel-time measurements.

Average Sound-Speed Profile

Individual sound-speed profiles suggested that the experiment was conducted in a single sound-speed profile volume. The individual profiles showed transient surface channels to varying depths and intermittent small depressed channels. Figure 5 contains a plot of the average sound speeds. The average sound-speed profile is characterized by a negative sound-speed gradient from the surface to 700 m, the depth of the deep sound-speed minimum. The transient surface and depressed channels present in the individual profiles were not retained in the average profile. During this run, the source ship reported 5- to 8-knot winds, 1-ft waves, and 8-ft swell, while the receiver ship reported 6-knot winds, ripples, and 4-ft swell. Sea-surface roughness measurements were obtained by the Waverider buoy from 1210 to 1506 LST. No measurements were obtained from 1507 LST to the end of the run at 1705 LST. Spectral analysis of the Waverider buoy measurements showed that the spectrum

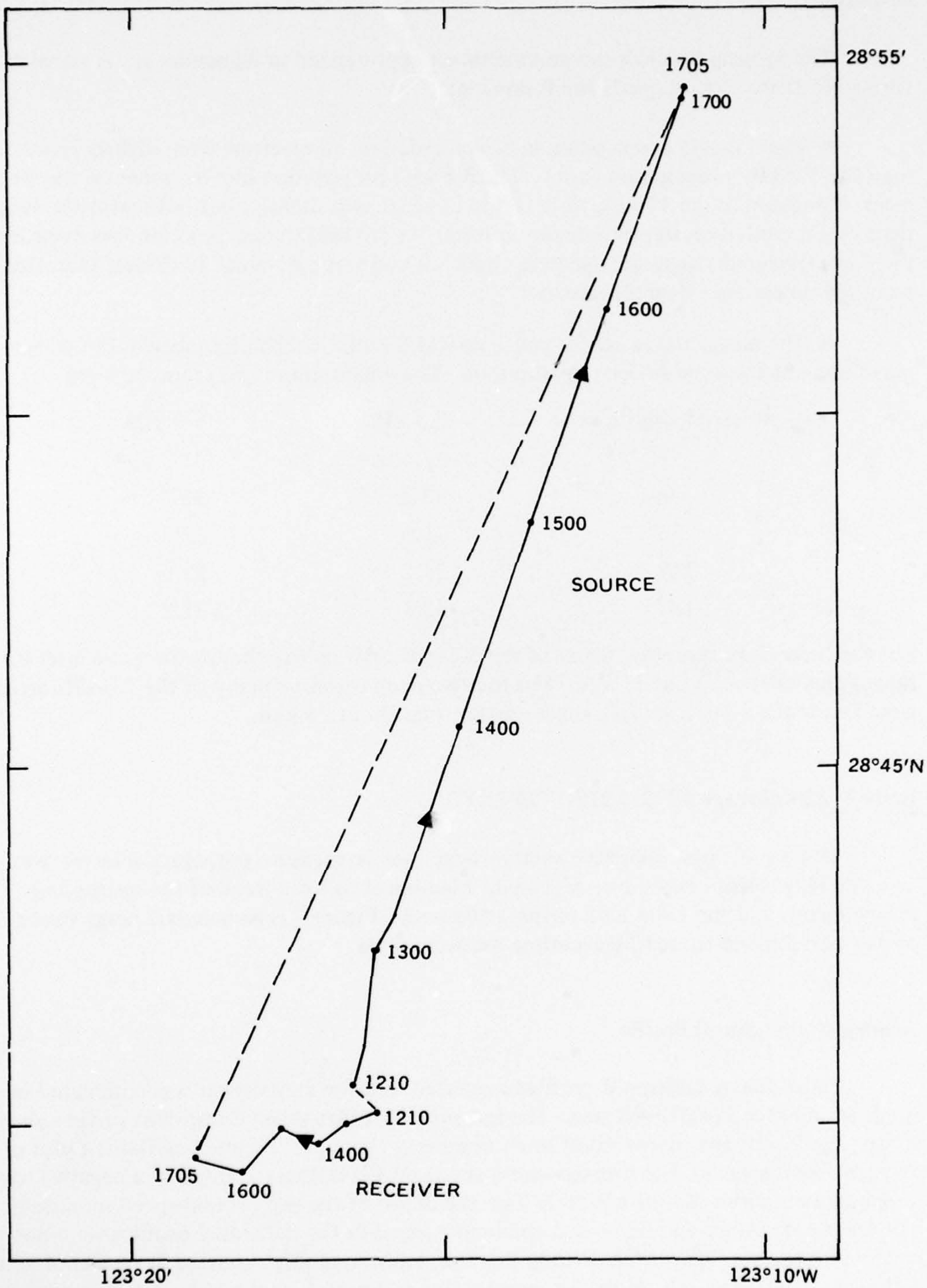


Figure 6. Station 4, run 2. Tracks of source and receiver ships and 1210 LST and 1705 LST propagation paths.

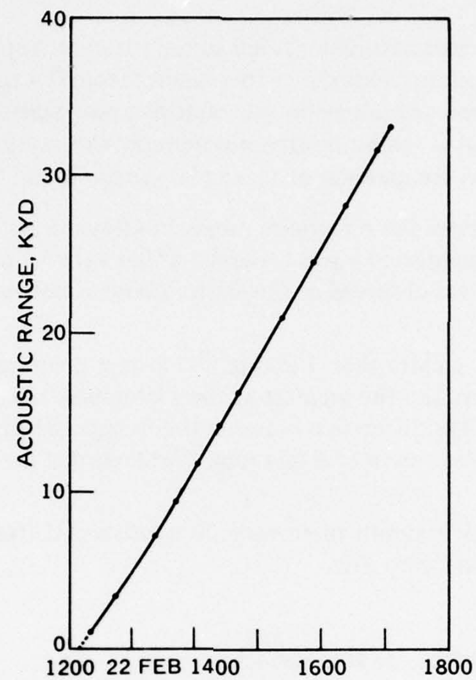


Figure 7. Station 4, run 2. Acoustic range versus time of day (*LST*).

changed with time during the run. The spectrum from 1214 to 1309 LST, the first hour of the run, showed that most of the roughness was centered in a wave-period band from 13.5 to 15.5 sec. The spectrum from 1310 to 1405 LST showed most of the roughness centered at a 14.0-sec wave period, with secondary peaks appearing at 9.8 and 10.8 sec. The spectrum for 1406 to 1501 LST showed most of the roughness still centered at 14.0 sec. However, the secondary-swell wave trains present during the previous hour decayed and were not detectable. All receivers were located in the negative sound-speed gradient.

AMOS Parameters

The number of observations and the average values of these parameters, derived from the thermistor chain temperature measurements and applicable to the run 2 experiment, are:

number of observations	1782
isothermal layer depth	0 ft
surface water temperature	59.5°F
sea state	1 → 2

Discussion

The propagation loss measurements are summarized in Appendix B. The data were analyzed with 1/3-octave filters centered at frequencies from 0.4 to 10.0 kHz. Data points not noise limited are plotted as squares on the explosive propagation loss figures, and noise-limited data as open triangles. Noise-limited points represent minimum propagation loss at the plotted range. A visual comparison of these plots suggests the following:

- Table 2 summarizes the maximum range, in kiloyards, of non-noise-limited arrivals. The largest propagation loss was observed at 0.4 kHz for all receiver depths. The smallest propagation loss was observed at the six frequencies between 1.0 and 10.0 kHz for the 6- and 36-m receivers.

- For frequencies greater than 1.0 kHz, the lowest propagation losses were recorded at the 6- and 36-m receivers and the greatest at the 117-m and 181-m receivers. Figure 8 is a plot of the propagation loss difference between the 6- and 181-m receivers. The propagation loss recorded on the 6-m receiver is less than that recorded on the 181-m receiver if the difference is positive.

- For a given receiver depth there were no consistent differences between the six frequencies between 1.0 and 10.0 kHz.

RUN 3 22-23 February 1972, 1810-0104 LST

During this run 1.5- and 2.5-kHz propagation losses were measured over acoustic ranges from 213 to 35.1 kyd. Figure 9 shows the tracks of the source and receiving ships and the 1810 LST propagation loss path. Figure 10 contains plots of source level and acoustic range, derived from 18 travel-time measurements, versus time of day.

Table 2. Maximum Range of Non-noise Limited Arrivals

Receiver	Frequency, kHz							
Depth, m	0.40	0.63	1.00	1.60	2.50	3.15	5.00	10.0
6	0.0	9.3	max	max	max	max	max	max
36	7.1	max	max	max	max	max	31.2	max
72	17.2	24.3	max	max	31.0	31.2	max	28.0
117	17.2	25.5	31.0	27.9	max	max	max	30.0
181	17.2	21.0	30.0	30.0	30.0	30.0	30.0	30.0

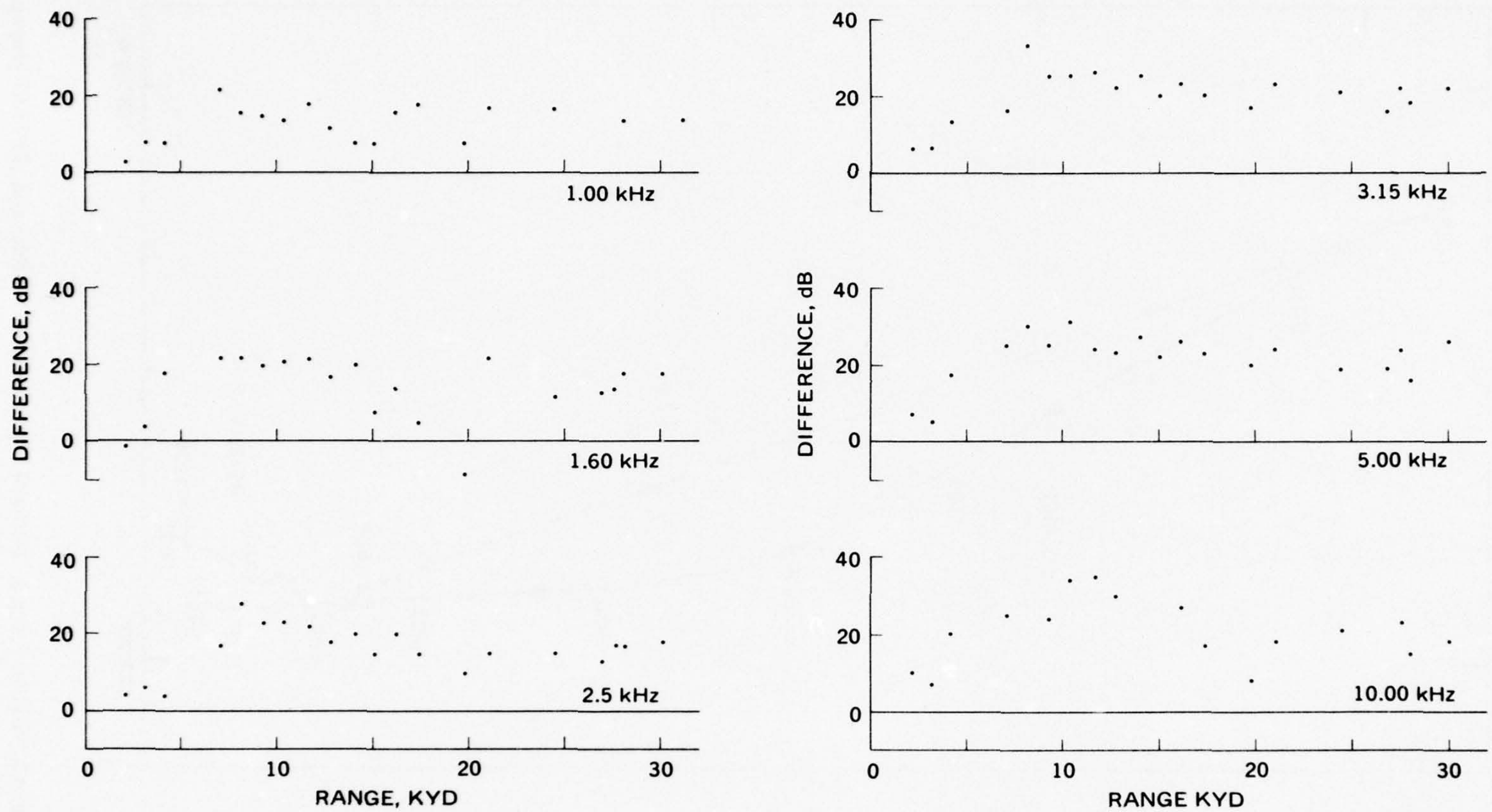


Figure 8. Station 4, run 2. Differences in propagation loss between 6-m and 181-m receivers.

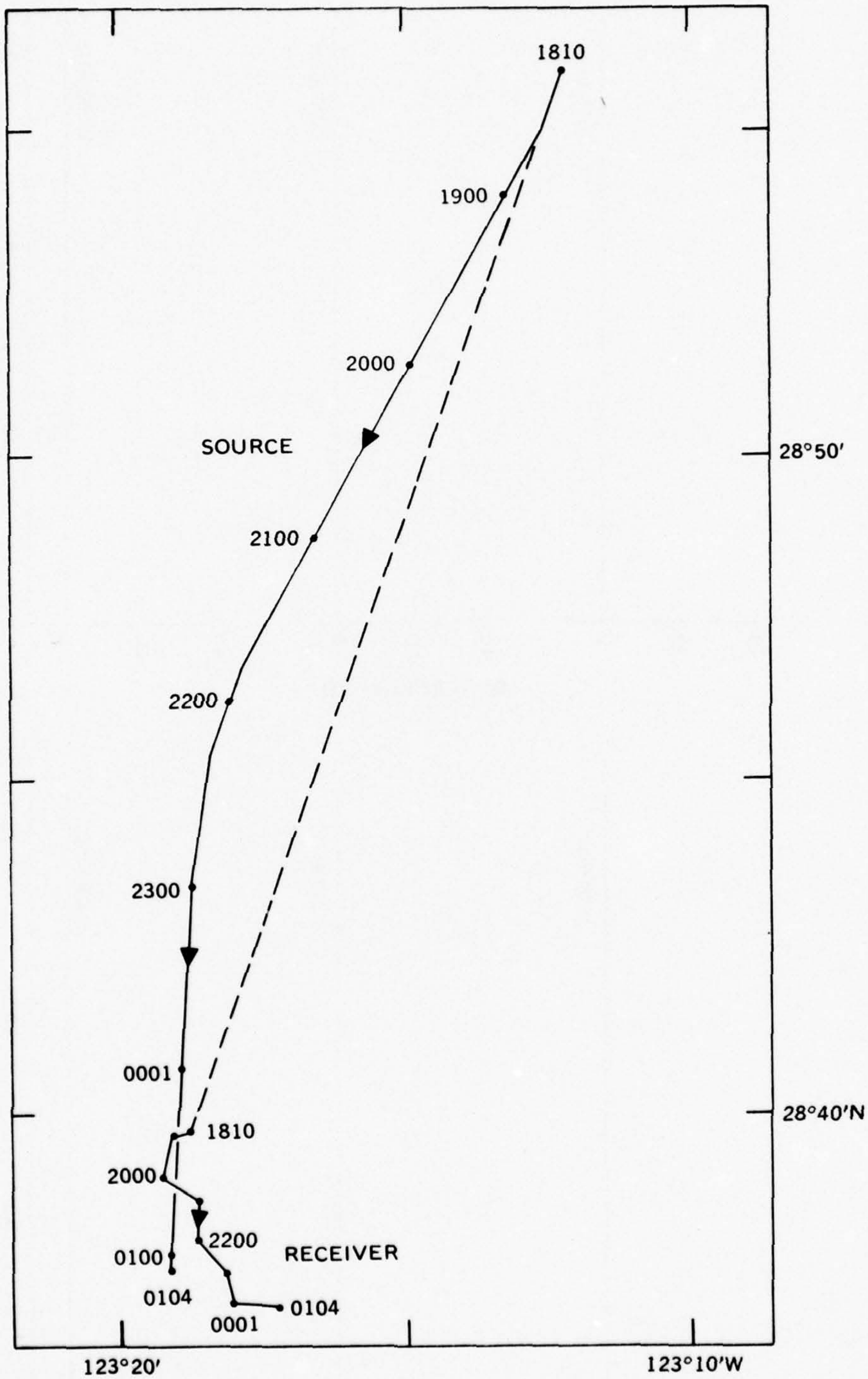
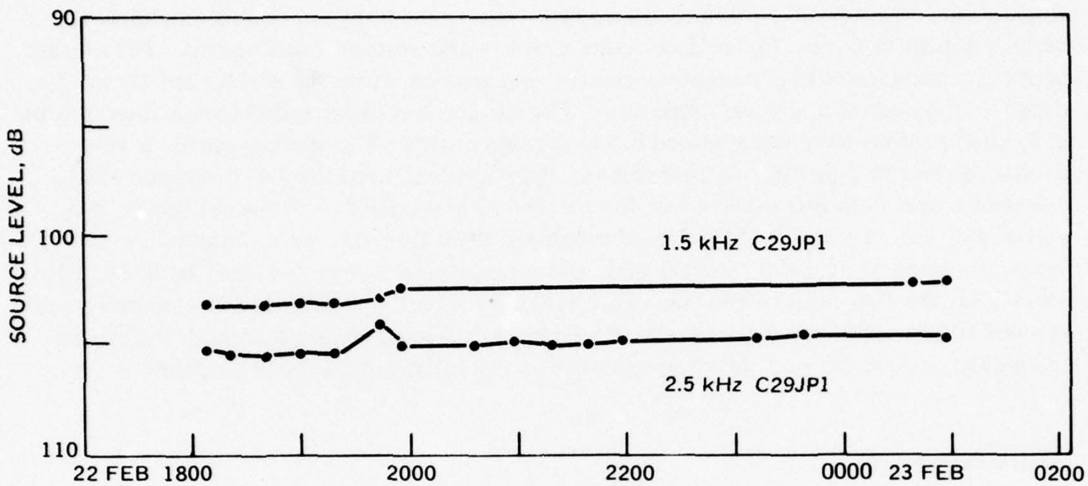


Figure 9. Station 4, run 3. Tracks of source and receiver ships and 1810 LST propagation path.



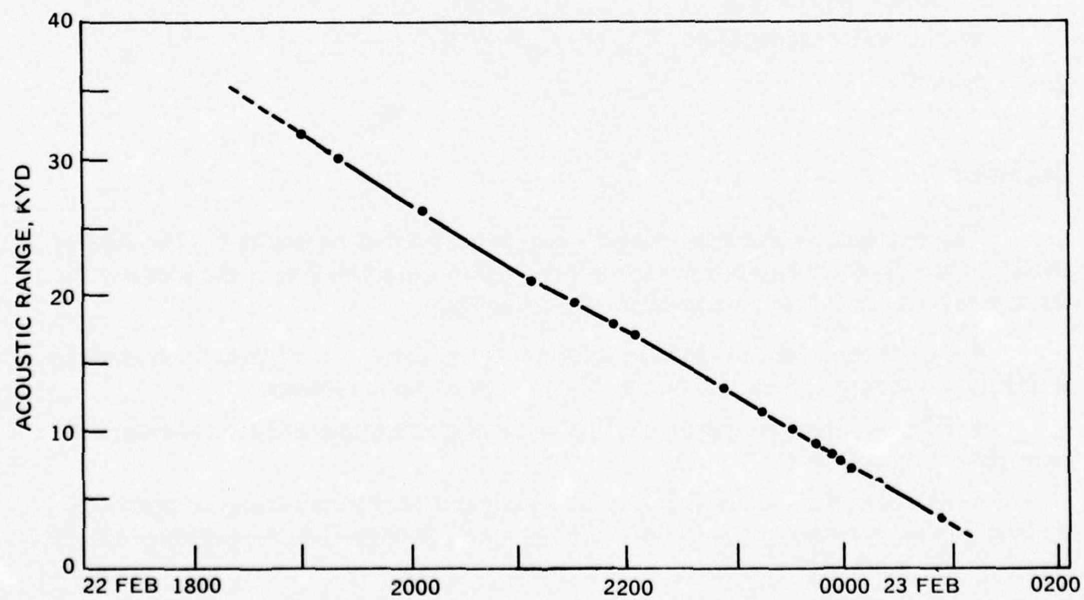


Figure 10. Station 4, run 3. Source level and acoustic range versus time of day (LST).

Average Sound-Speed Profile

Individual sound-speed profiles suggested that the experiment was conducted in a single sound-speed profile volume. These profiles showed transient surface channels at various depths to 67 m. Figure 5 contains a plot of the average sound speeds. The average profile is characterized by a negative sound-speed gradient from the surface to 700 m, the depth of the deep sound-speed minimum. The surface and depressed channels shown in the individual profiles were not retained in the average profile. The average profile is very similar to the run 2 profile. During this run the source ship reported 4- to 8-knot winds, 1-ft waves, and 7- to 8-ft swell, while the receiver ship reported 7- to 8-knot winds, 1-ft waves, and 3- to 4-ft swell. Sea-surface roughness measurements were obtained by the Waverider buoy from 1900 to 0104 LST. No measurements were obtained from 1810 to 1859 LST, the first hour of the run. Spectral analysis of the Waverider buoy measurements showed that most of the variance was in a wave-period band centered at 12.6 sec, with a secondary peak at 7.8 sec. All receivers were in a negative sound-speed gradient.

AMOS Parameters

The number of observations and the average values of these parameters, derived from the thermistor chain temperature measurements, and applicable to the run 3 experiments are:

number of observations	2493
isothermal layer depth	0 ft
surface water temperature	59.5°F
sea state	2

Discussion

The propagation loss measurements are summarized in Appendix C. The missing arrivals in the 27- to 29-kyd range interval were due to a malfunction of the sources. A visual comparison of these plots suggests the following:

- At both frequencies the propagation loss recorded on the 6- and 36-m receivers is slightly less than that recorded on the 72-, 117-, and 180-m receivers.
- For any given receiver depth, there is no frequency dependence shown in the propagation loss patterns.
- Although the average sound-speed profile did not have a surface or depressed channel, the propagation loss patterns exhibited a well-developed modal pattern, especially for the propagation losses recorded on the shallower receivers.
- The maximum range for run 3 was 35.1 kyd. The maximum range was recorded for both frequencies at all receiver depths.

RUN 4 23 February 1972, 0116-0632 LST

During this run, 1.5- and 2.5-kHz propagation losses were measured over acoustic ranges from 2.6 to 33.4 kyd. Figure 11 shows the tracks of the source and receiving ships and the 0632 LST propagation paths. The source ship reported 8- to 10-knot winds, 1-ft waves, and 8-ft swell, while the receiving ship reported 8- to 10-knot winds, 1-ft waves, and 3- to 4-ft swell. Figure 12 contains plots of source level and acoustic range, derived from 7 travel-time measurements, versus time of day.

Average Sound-Speed Profile

Individual sound-speed profiles suggested that the experiment was conducted in a single sound-speed profile volume. These profiles exhibited transient surface channels to varying depths and intermittent small depressed channels. Figure 5 contains a plot of the average sound-speed profile. The average profile is characterized by a 10-m surface channel. The transient depressed channels observed in individual profiles was not preserved in the average profile. Sea-surface roughness measurements were obtained by the Waverider buoy for the complete run. Spectral analysis of the Waverider buoy measurements showed a change with time during the last hour of the experiment. From 0116 to 0527 LST, the first 4 hr 11 min of the run, most of the sea-surface roughness was contained in two trains of swell centered at 12.5 sec and 15.7 sec wave periods. The spectrum from 0528 to 0630 LST also showed two swell trains. However, the 12 5-sec swell shifted period to about 11.7 sec. During the last hour, wind waves centered at about 3.2 sec appeared. Receiver 1 was located in the surface channel, receivers 2 and 3 in a small negative sound-speed gradient layer, and receivers 4 and 5 in the main thermocline.

AMOS Parameters

The number of observations and the average values of these parameters, derived from the thermistor chain temperature measurements, and applicable to the run 4 experiment are:

number of observations	1854
isothermal layer depth	36 ft
surface water temperature	59.9°F
sea state	2

Discussion

The propagation loss measurements are summarized in Appendix D. A visual comparison of these plots suggests the following:

- Although the average sound-speed profile was characterized by a 10-m surface channel, the 6-m receiver recorded all transmitted pulses out to only 4.6 kyd (1.5 kHz) and 5.1 kyd (2.5 kHz). At greater ranges there were many range intervals in which many, most,

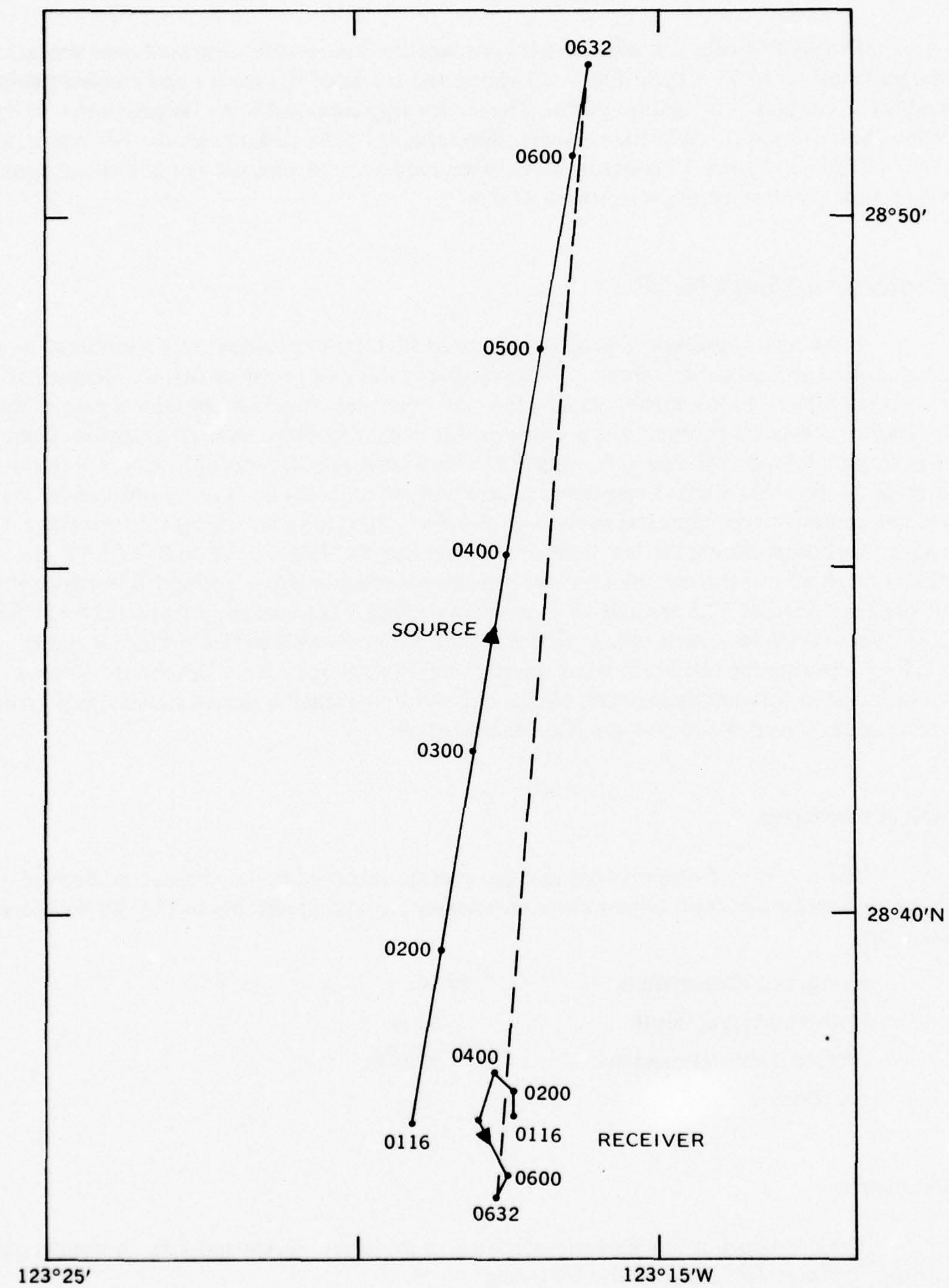


Figure 11. Station 4, run 4. Tracks of source and receiver ships and 0632 LST propagation paths.

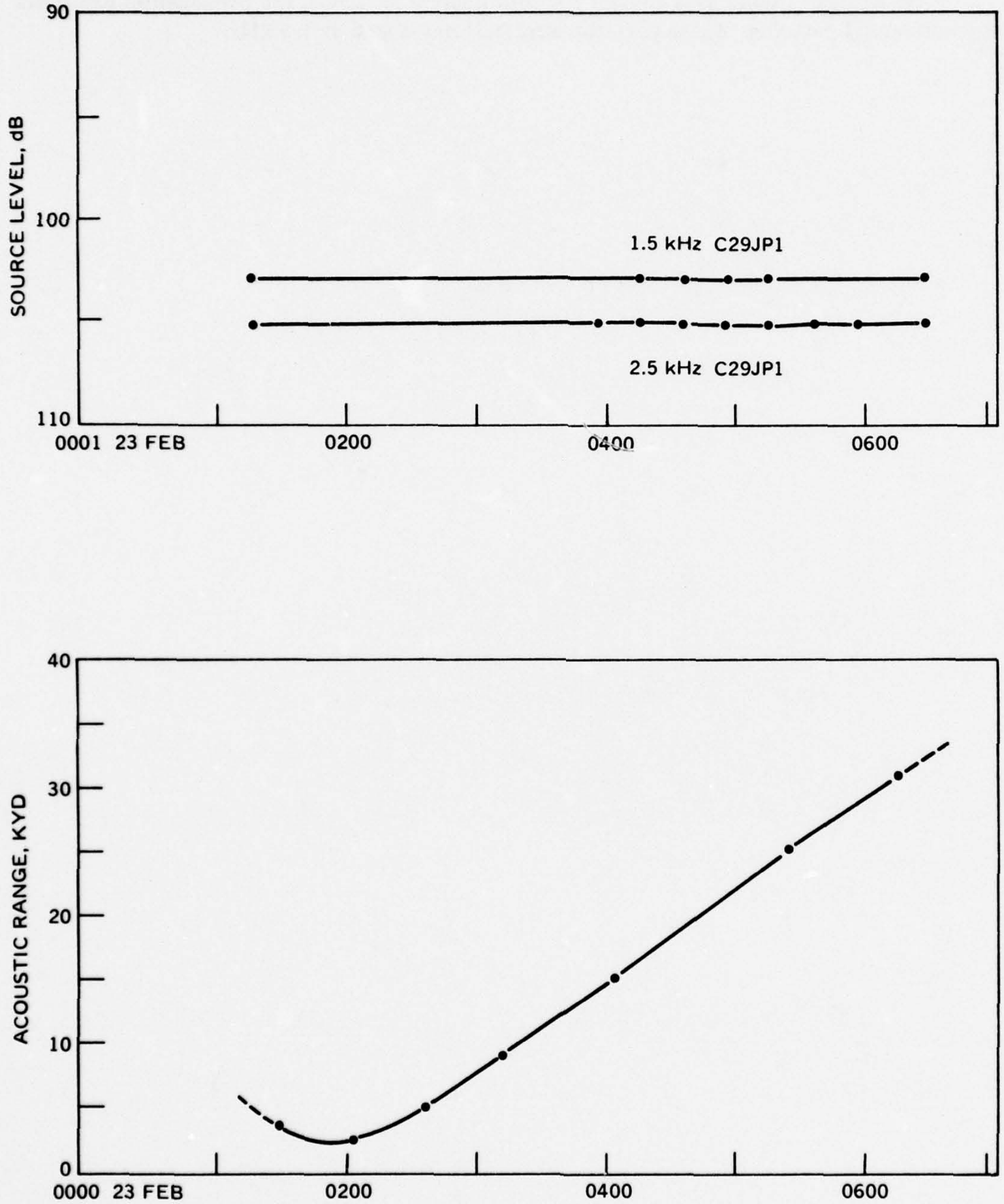


Figure 12. Station 4, run 4. Source level and acoustic range versus time of day (LST).

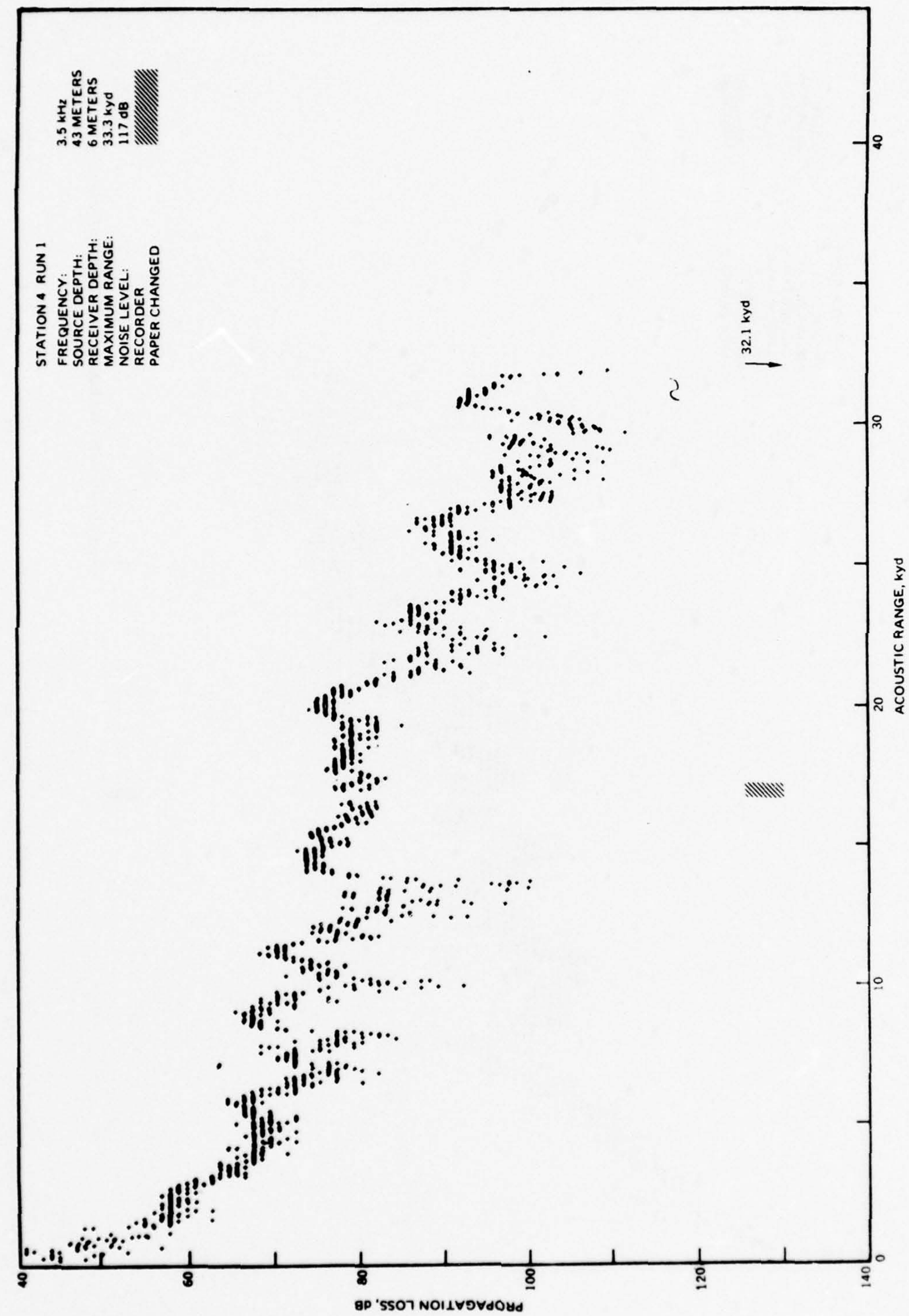
or all of the transmitted pulses were below the noise level. It is somewhat paradoxical that at 2.5 kHz, all 6-m pulses were received from 30.1 kyd to the end of the run at 33.4 kyd.

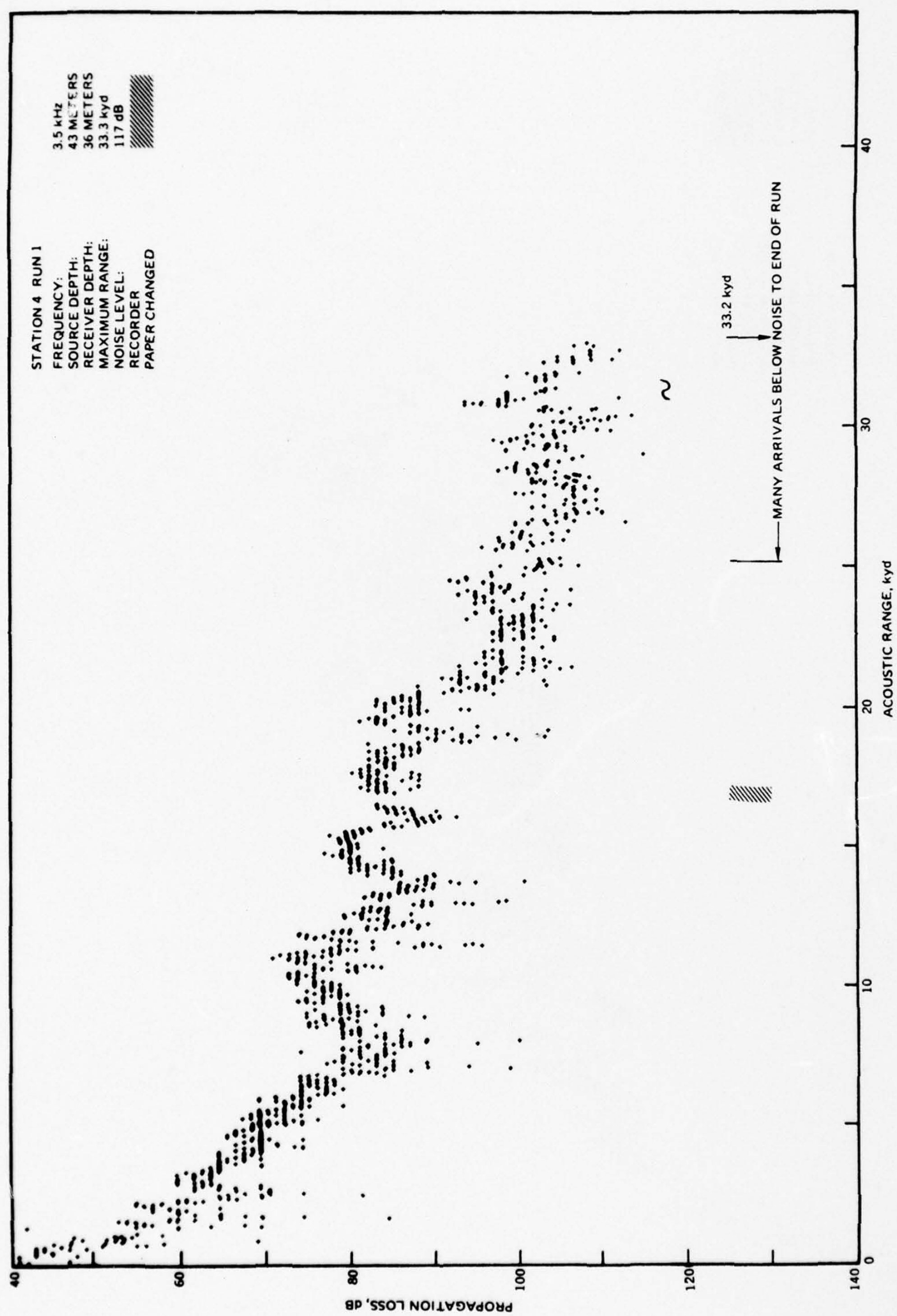
- At both frequencies and for the four deepest receivers, the propagation loss plots showed modal patterns. These patterns were best developed at 1.5 kHz.

APPENDIX A

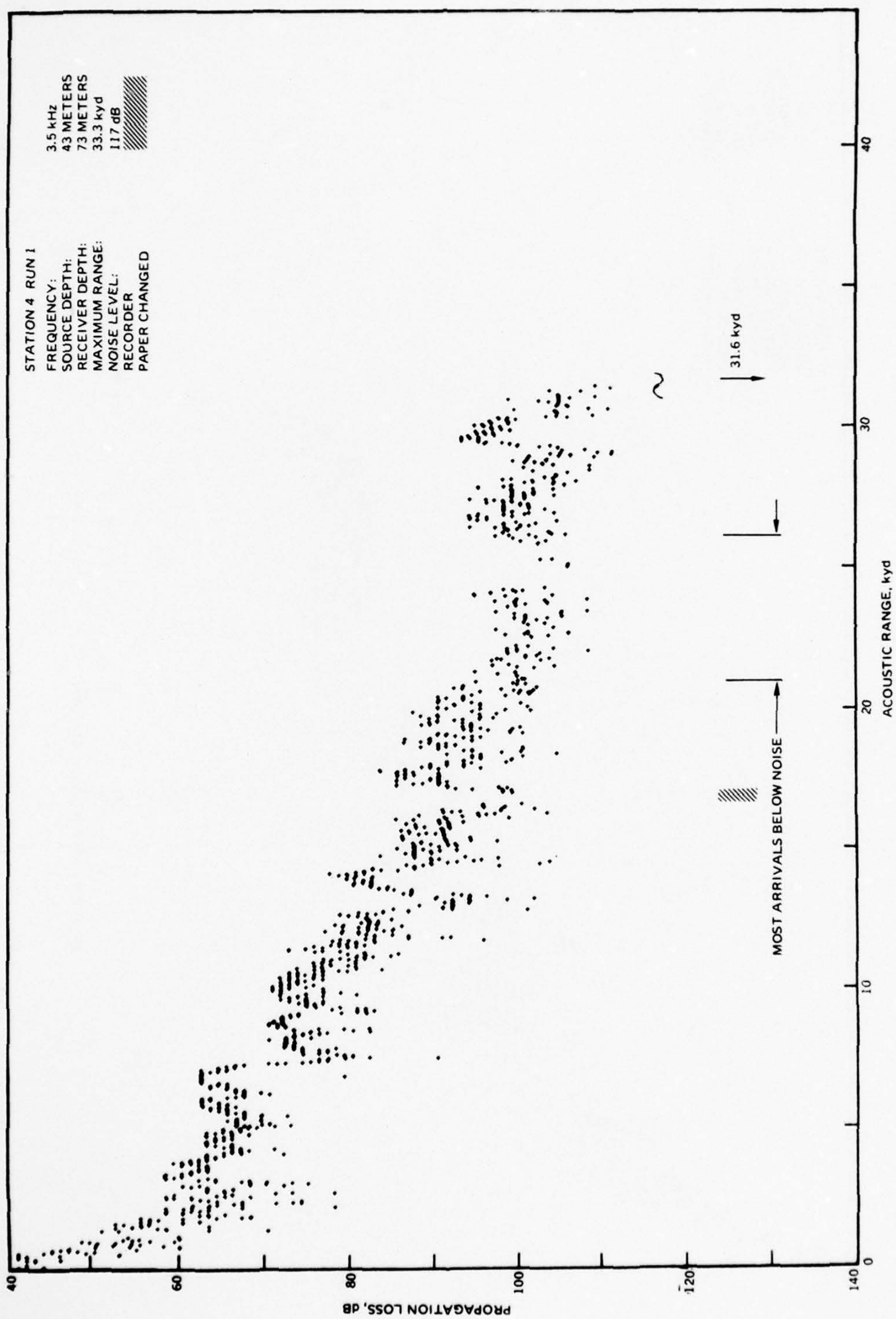
STATION 4 RUN 1

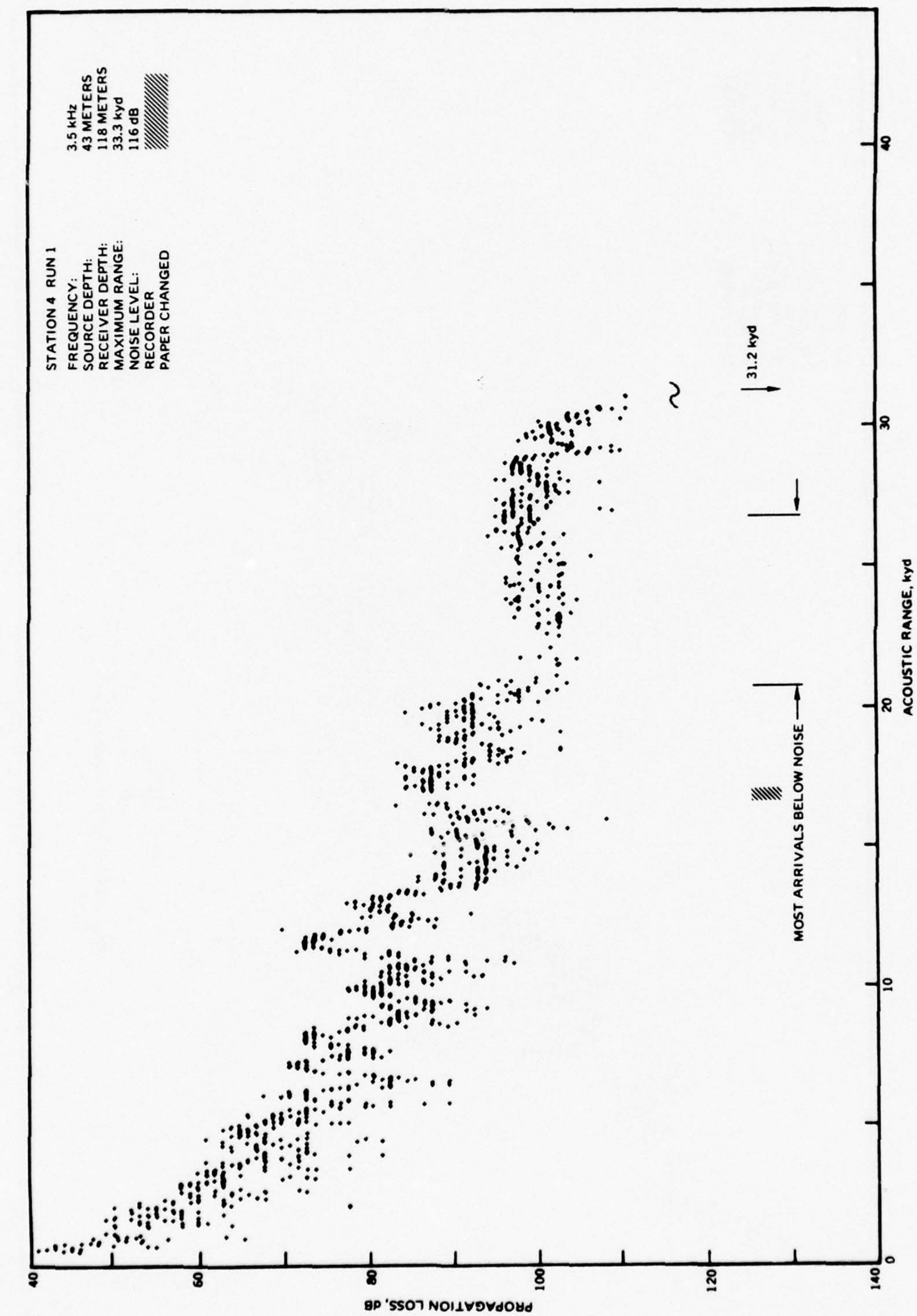
PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

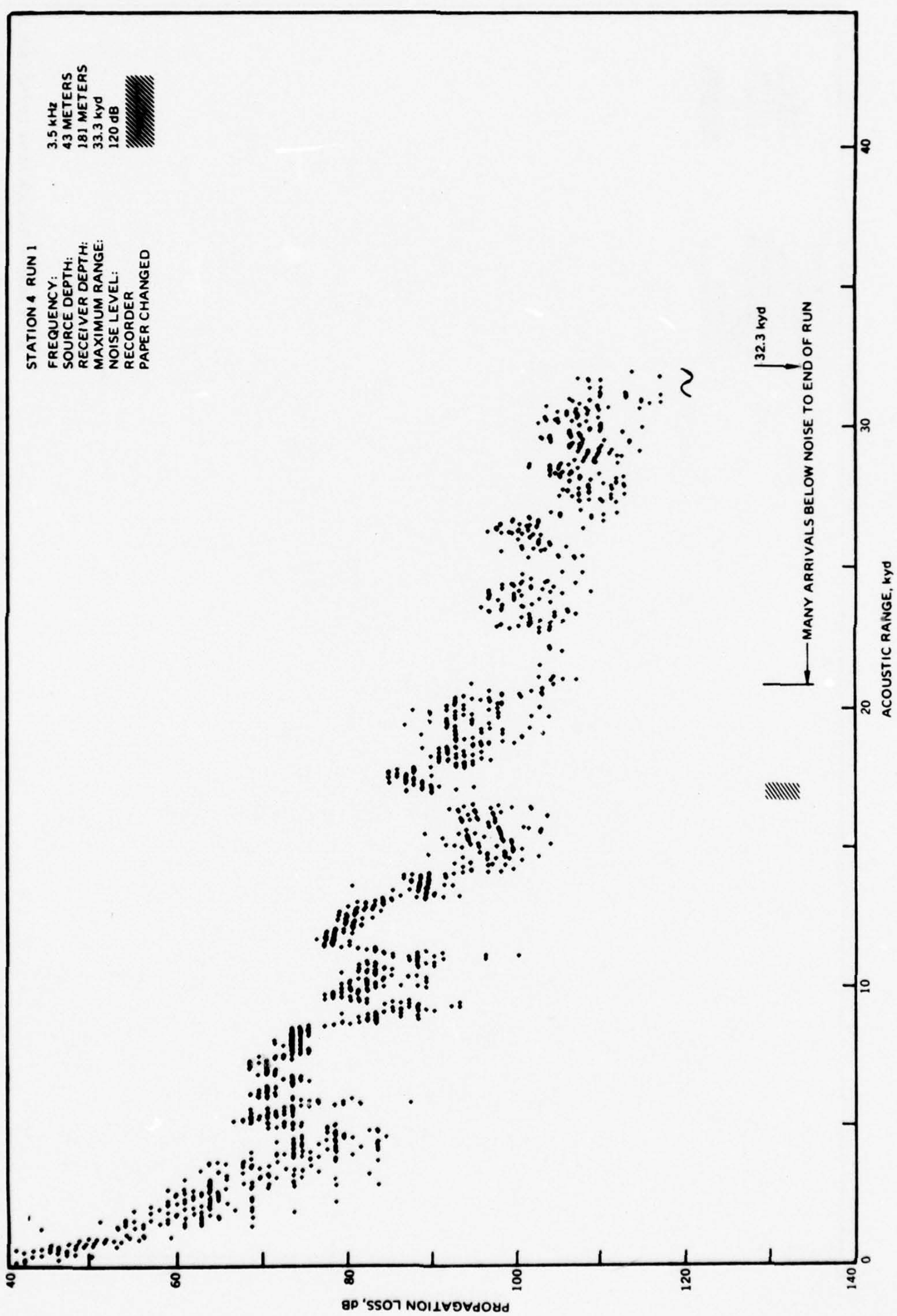

STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 117 dB
RECORDER PAPER CHANGED
32.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

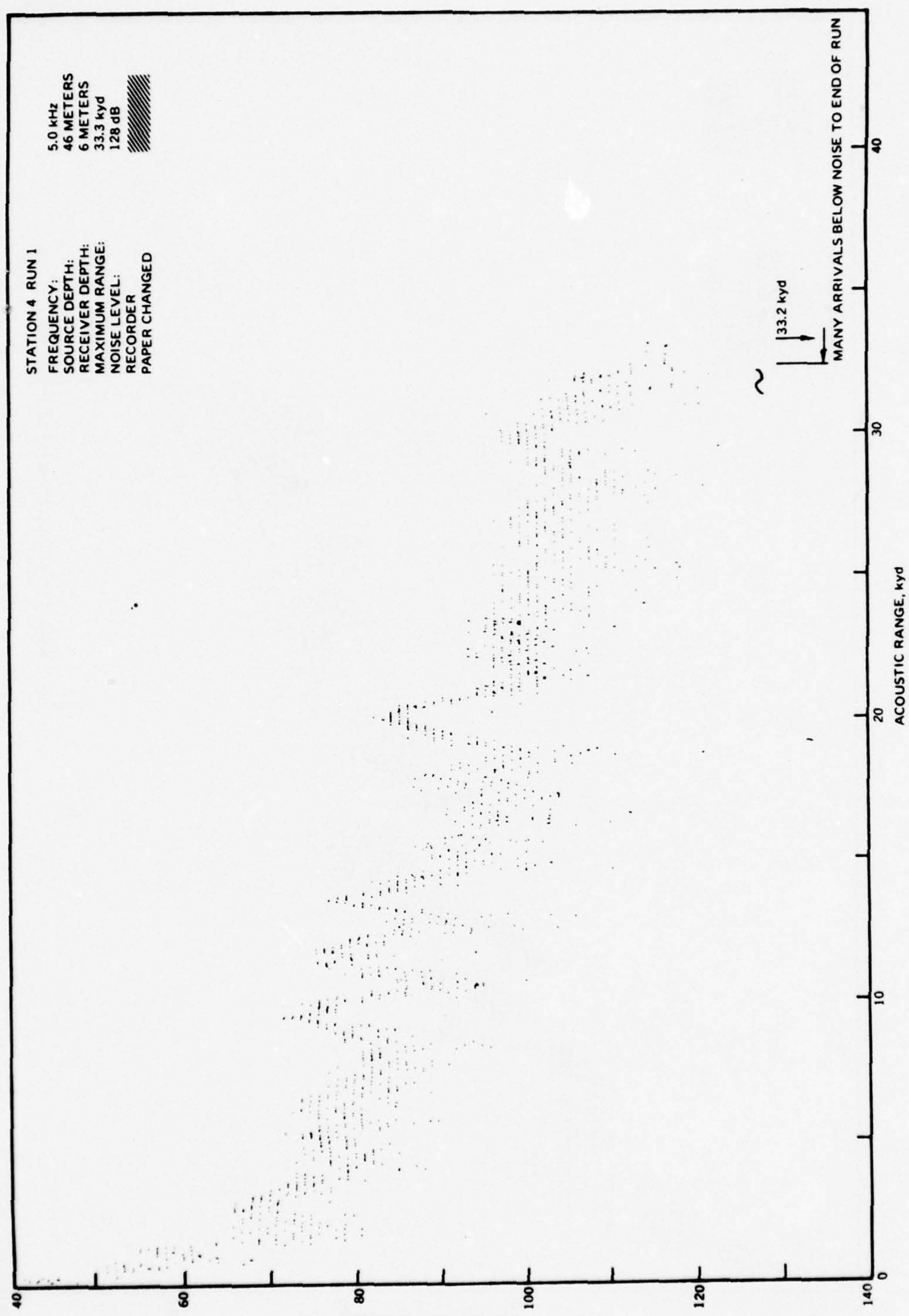


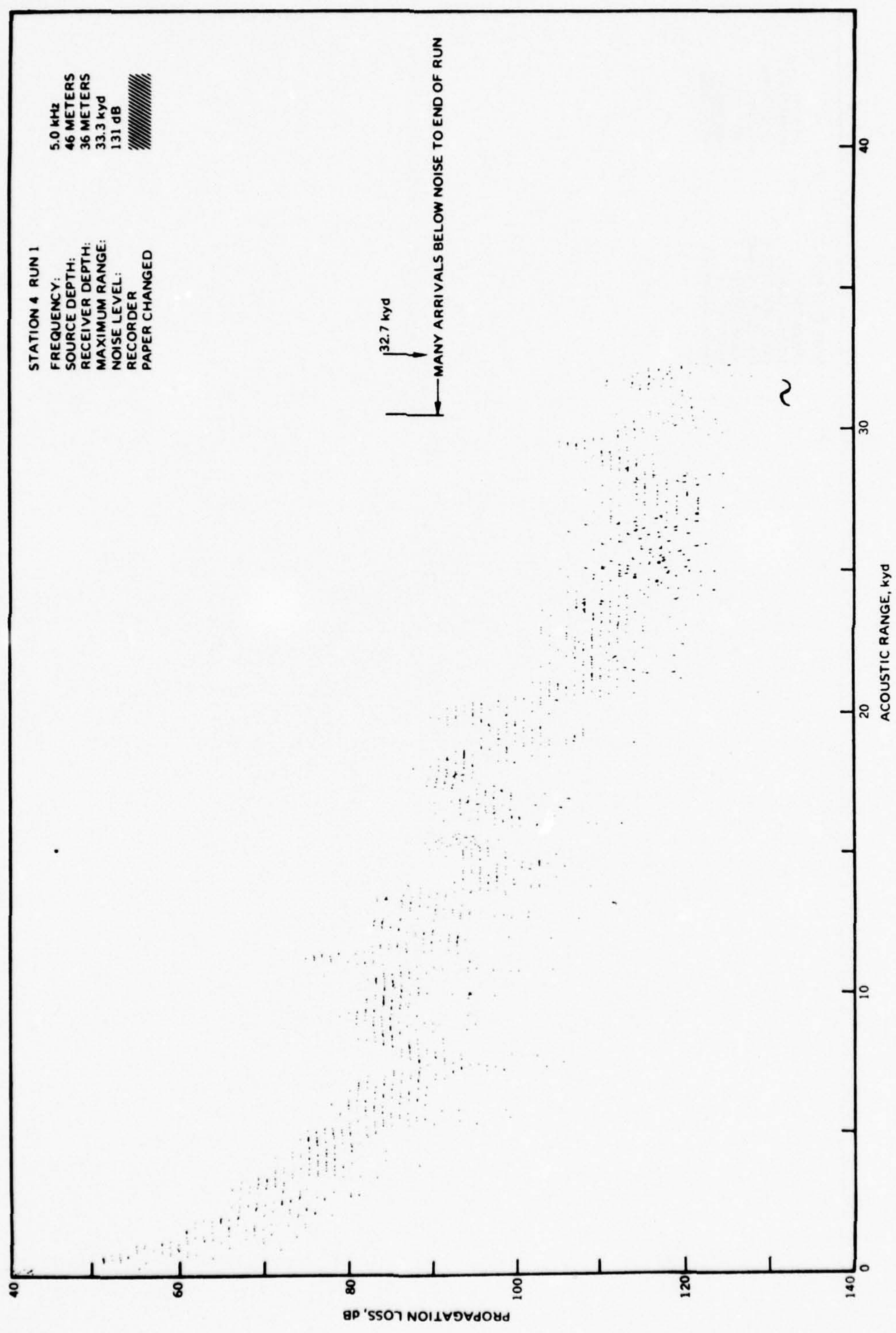
STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 117 dB
RECORDER PAPER CHANGED
33.2 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
ACOUSTIC RANGE, kyd
0
10
20
30
40
PROPAGATION LOSS, dB
40
60
80
100
120
140


STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 73 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 117 dB
RECORDER PAPER CHANGED
31.6 kyd
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

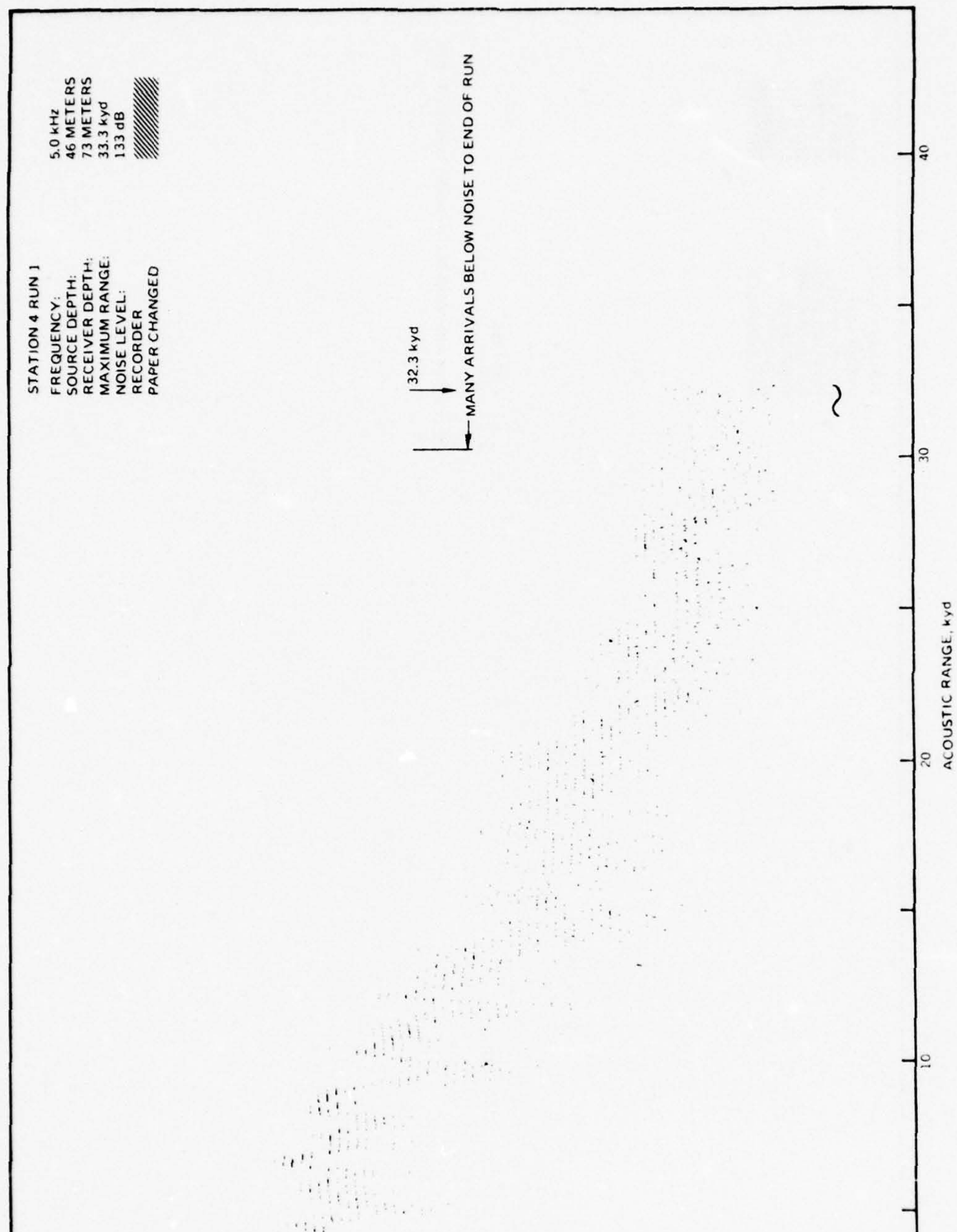

STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 118 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 116 dB
RECORDER PAPER CHANGED
31.2 kyd
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

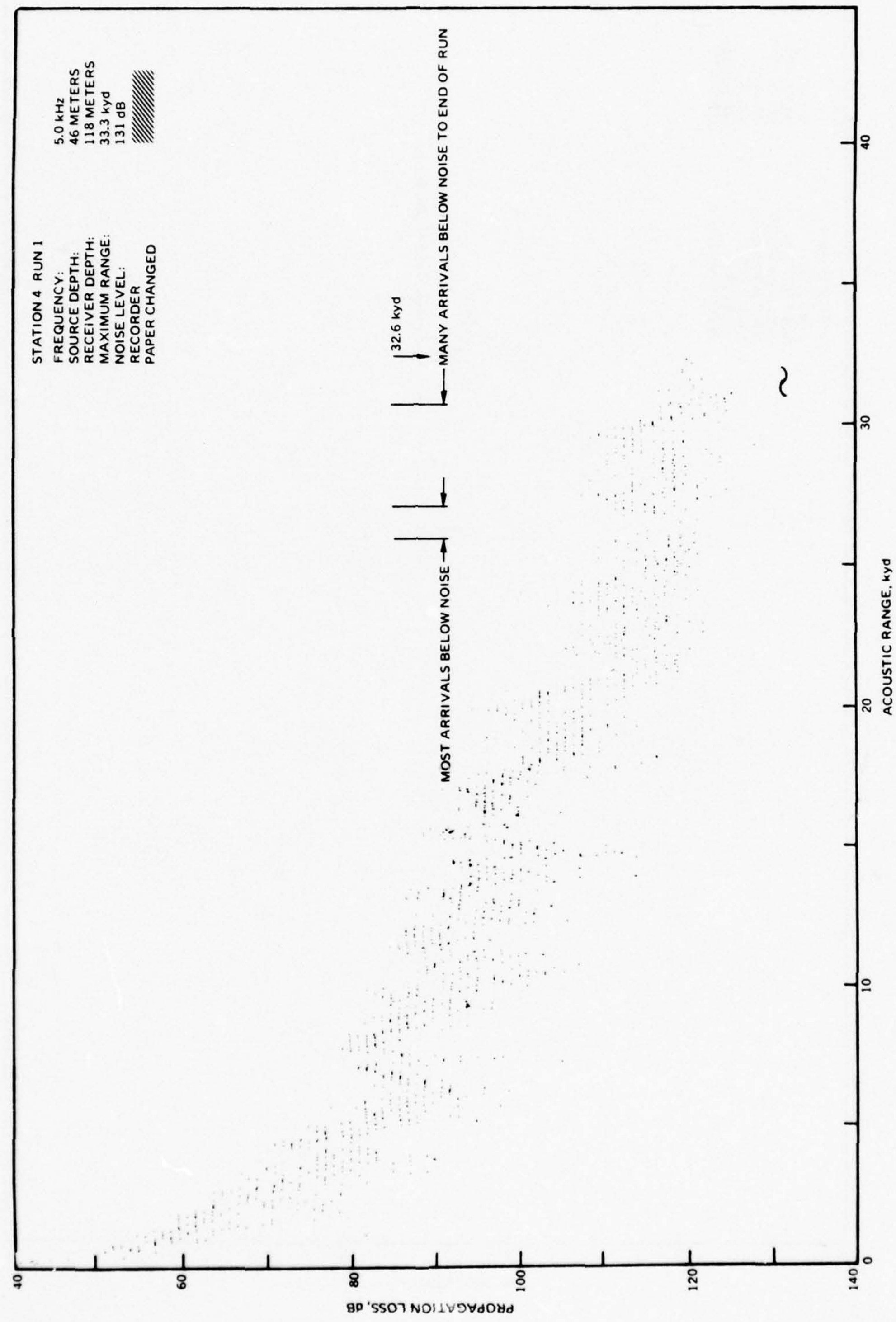

STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 181 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 120 dB
RECORDER PAPER CHANGED
32.3 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

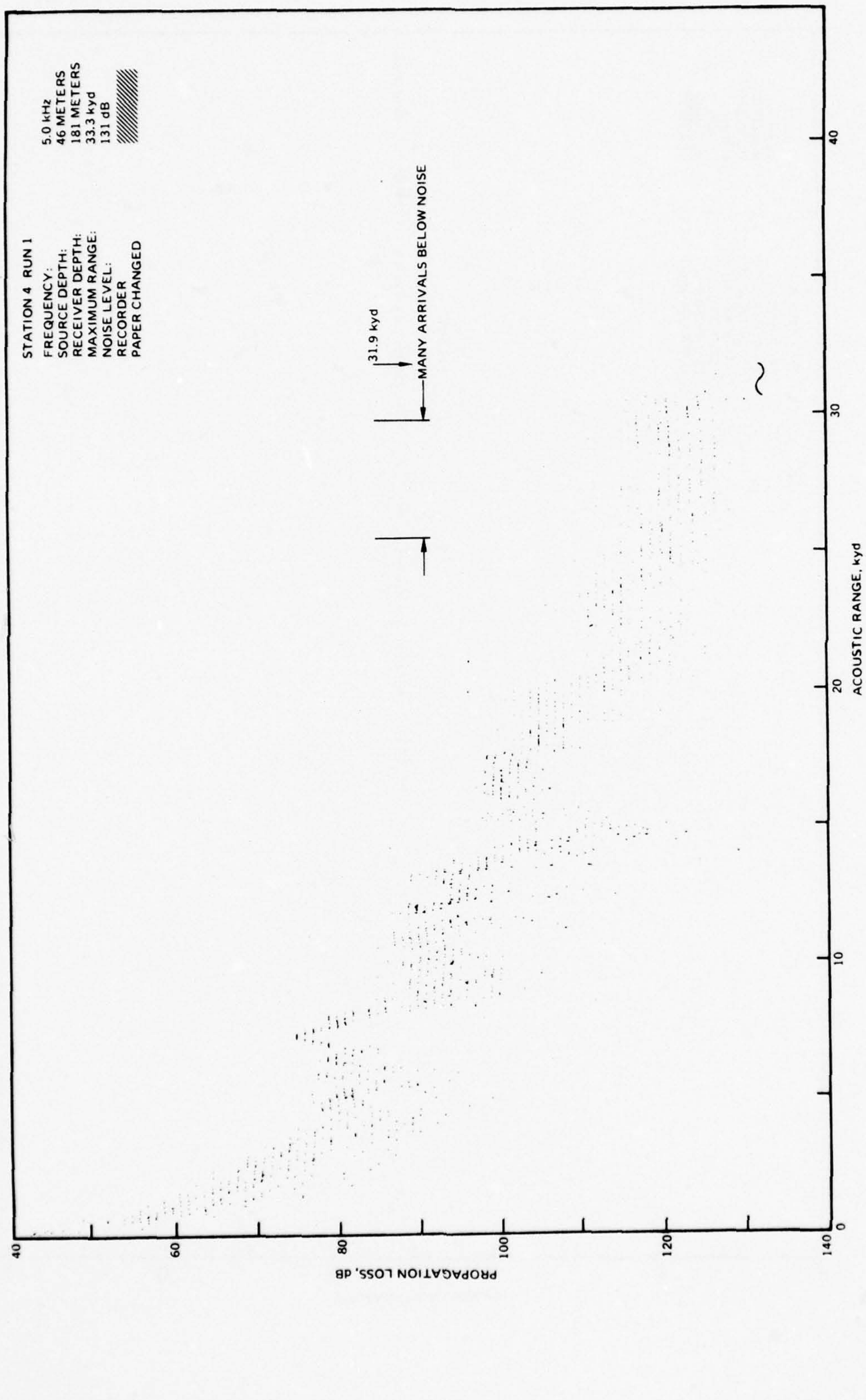

STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 128 dB
RECORDER PAPER CHANGED
33.2 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40



STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 131 dB
RECORDER PAPER CHANGED
32.7 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40


STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 73 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 133 dB
RECORDER PAPER CHANGED
32.3 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
40
60
80
100
120
140


STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 118 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 131 dB
RECORDER PAPER CHANGED
32.6 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

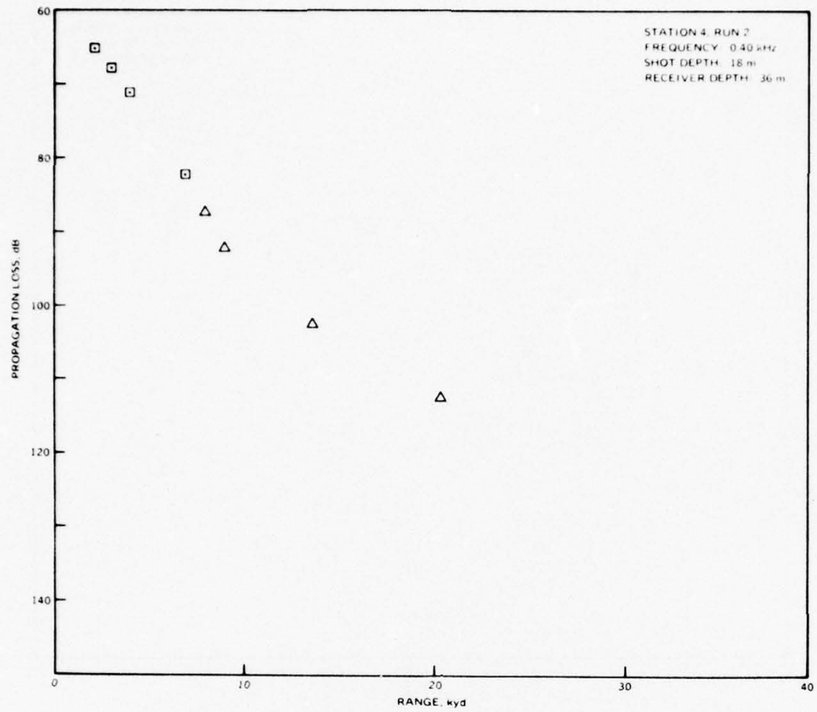


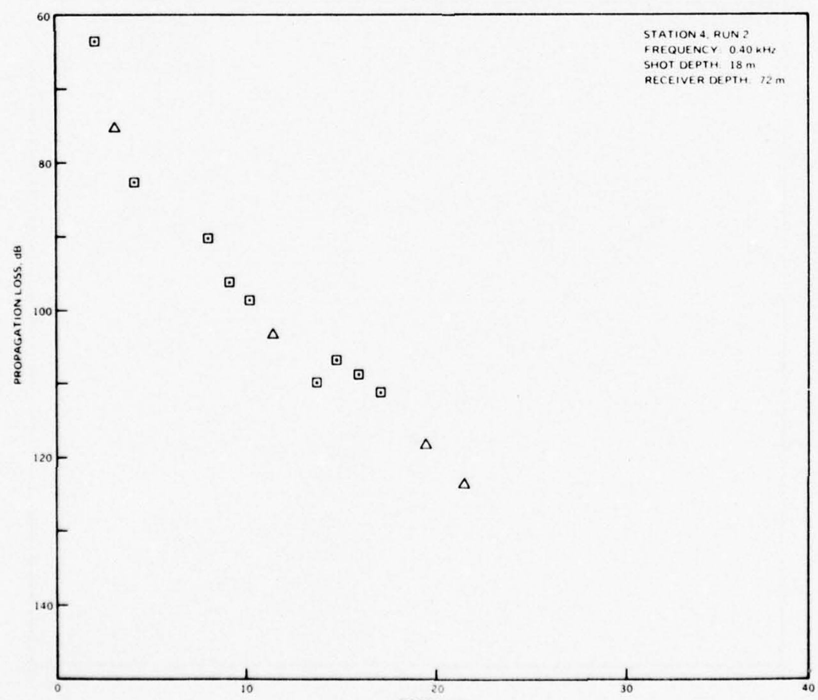
STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 181 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 131 dB
RECORDER PAPER CHANGED
31.9 kyd
MANY ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

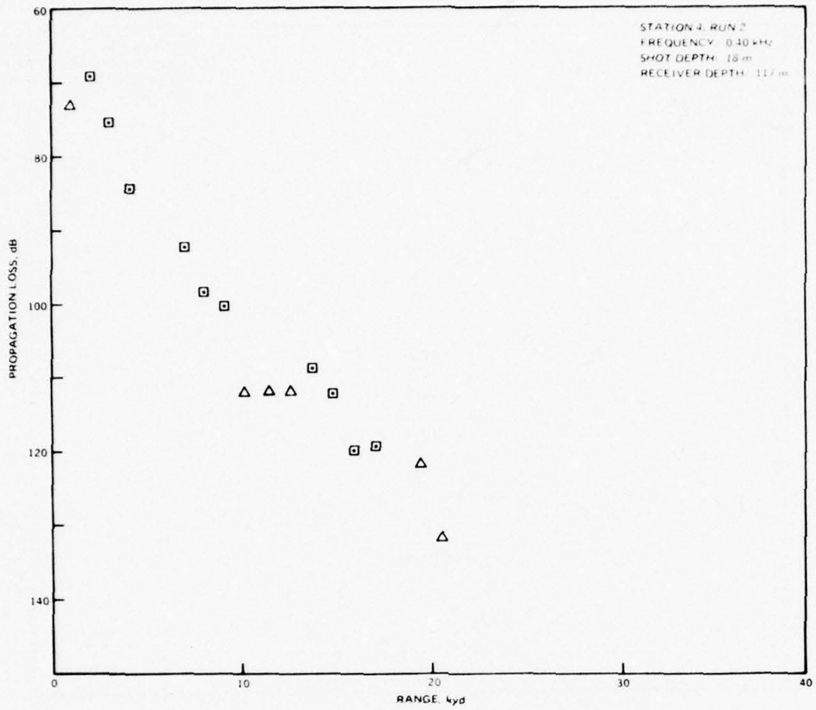
APPENDIX B

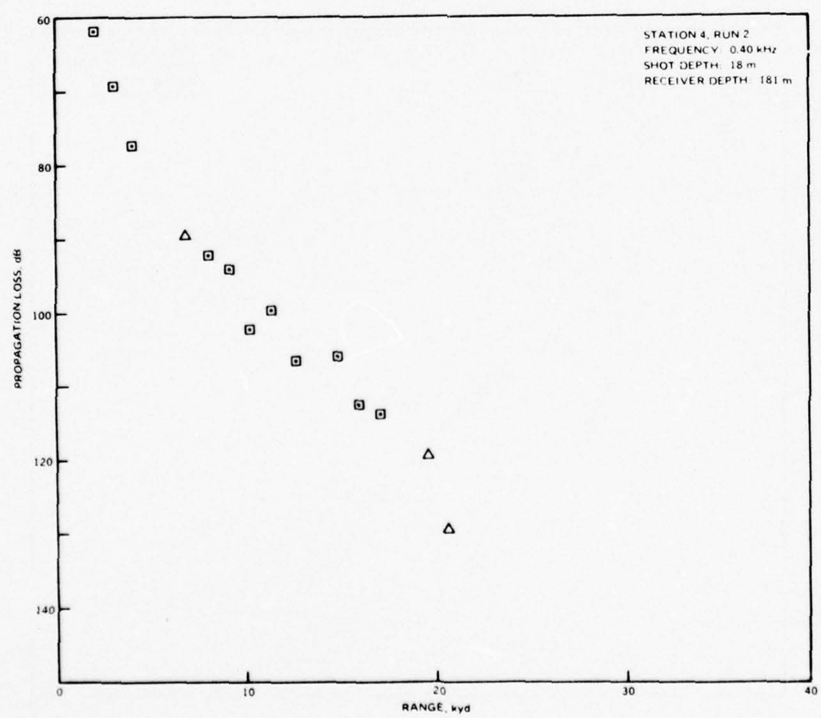
STATION 4 RUN 2

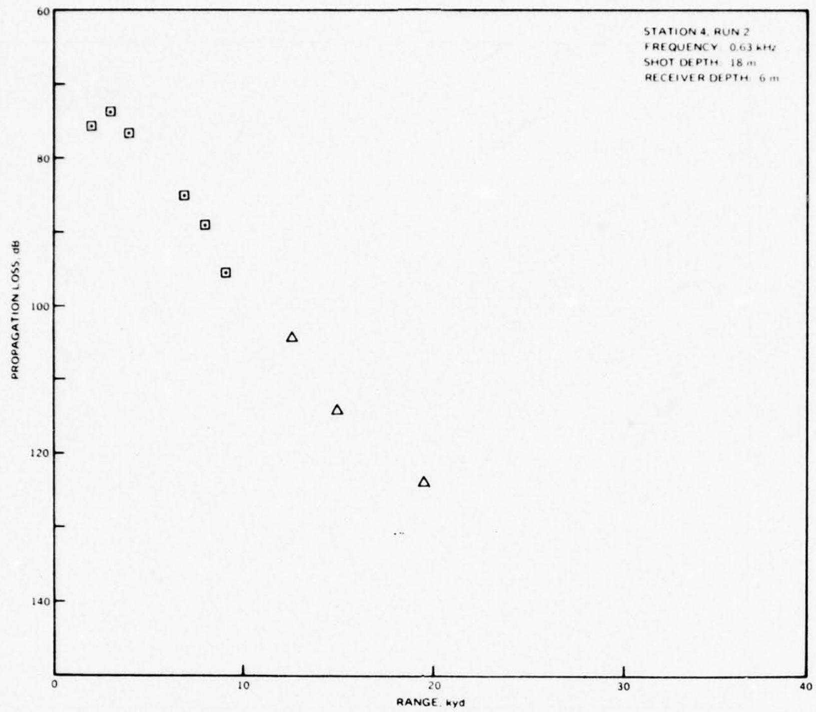
PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

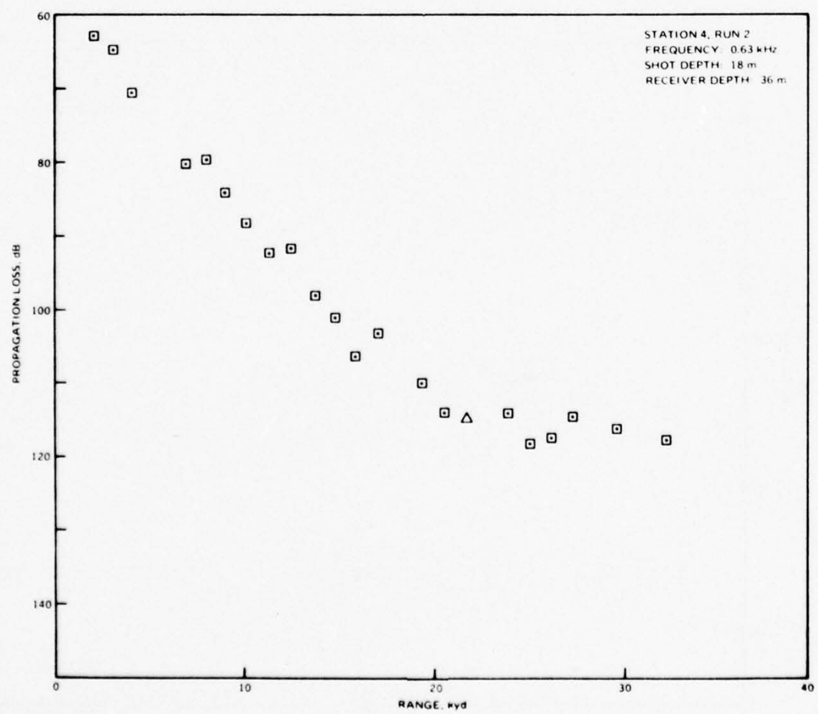

STATION 4, RUN 2
FREQUENCY: 0.40 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 36 m
PROPAGATION LOSS, dB
RANGE, kyd

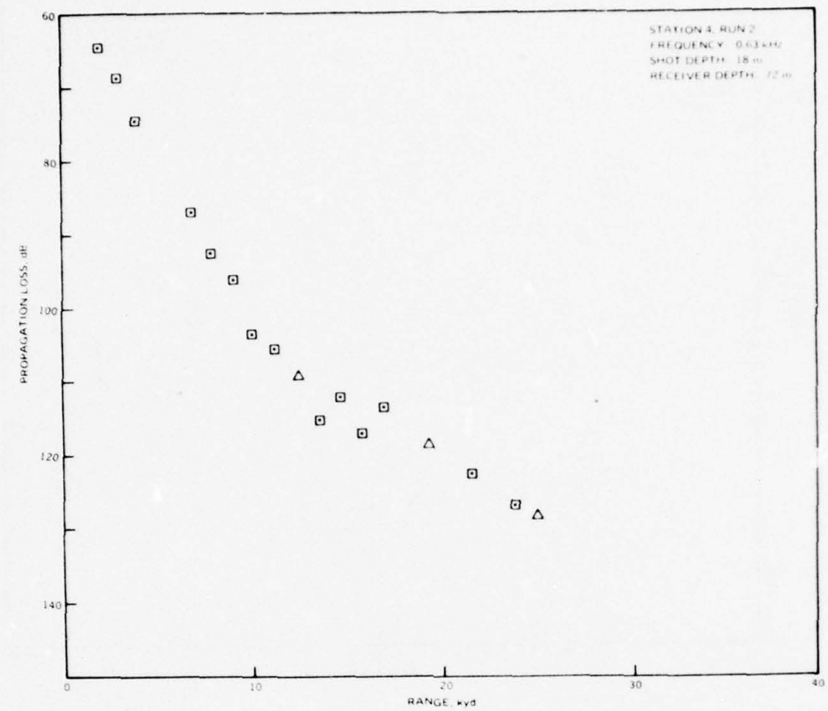

STATION 4, RUN 2
FREQUENCY: 0.40 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 72 m
PROPAGATION LOSS, dB
RANGE, kyd

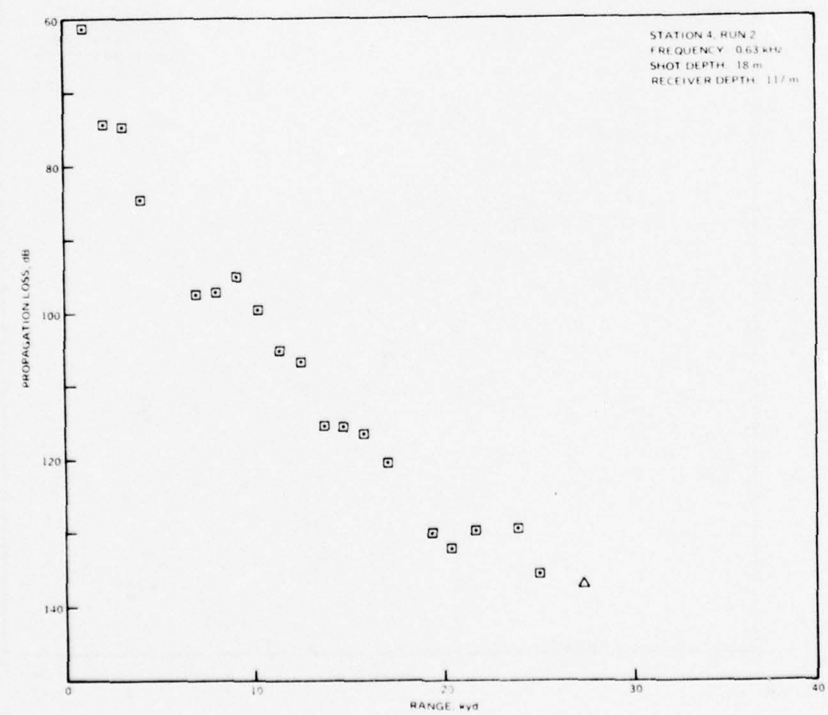

STATION 4, RUN 2
FREQUENCY 0.40 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 117 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

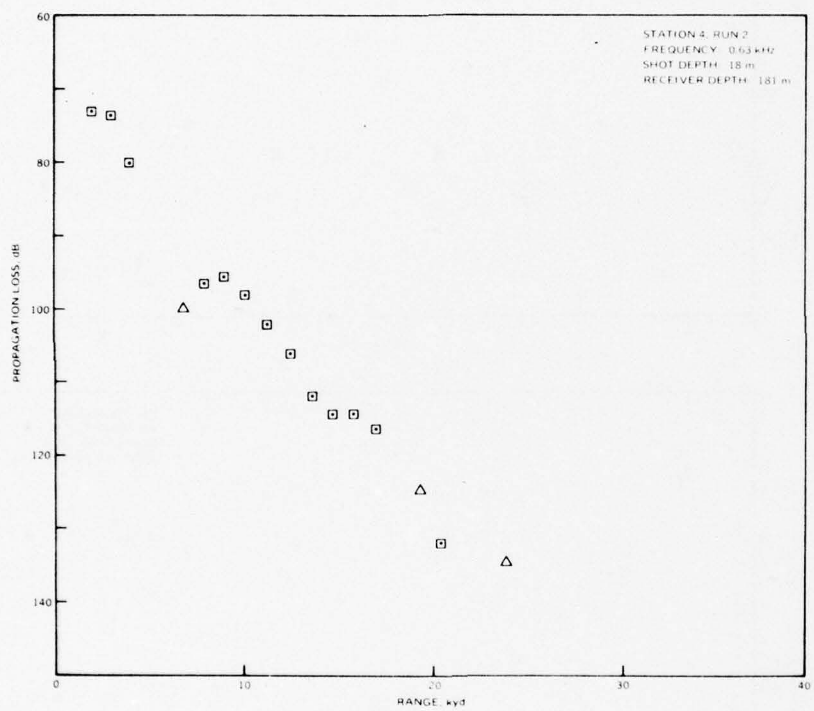

STATION 4, RUN 2
FREQUENCY 0.40 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 181 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

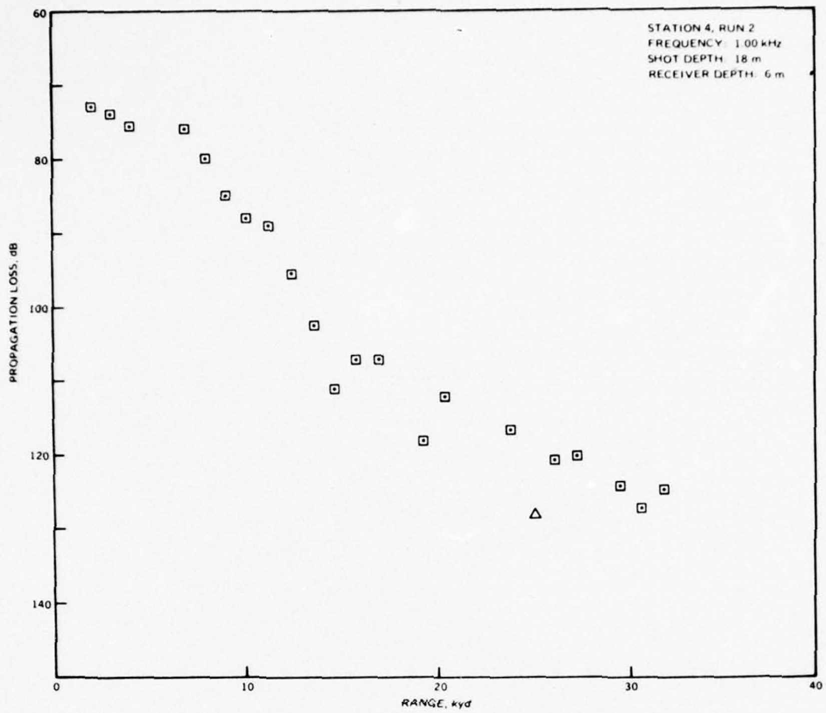

STATION 4, RUN 2
FREQUENCY: 0.63 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

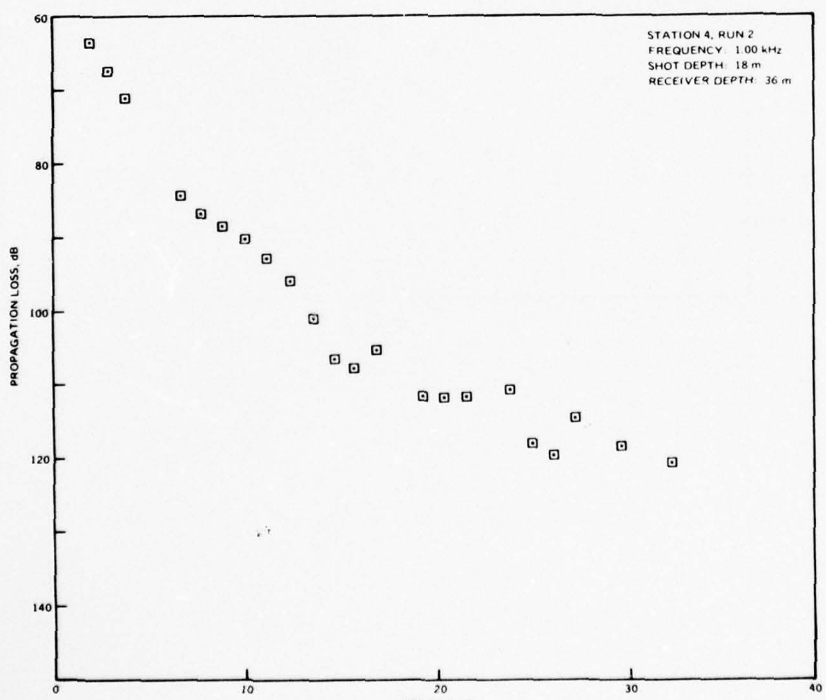

STATION 4, RUN 2
FREQUENCY: 0.63 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 36 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

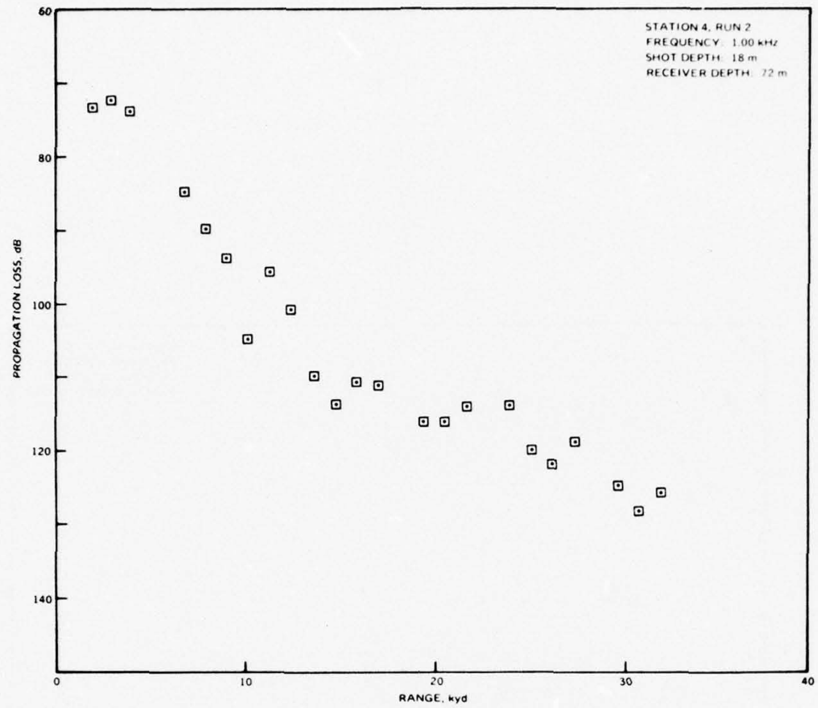

STATION 4, RUN 2
FREQUENCY 0.63 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 72 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

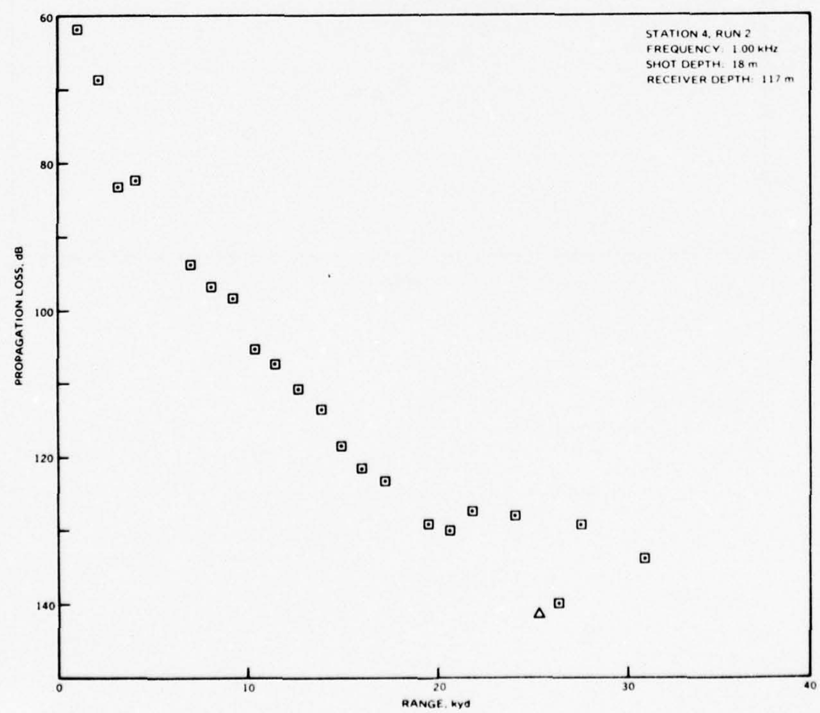

STATION 4, RUN 2
FREQUENCY 0.63 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 117 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

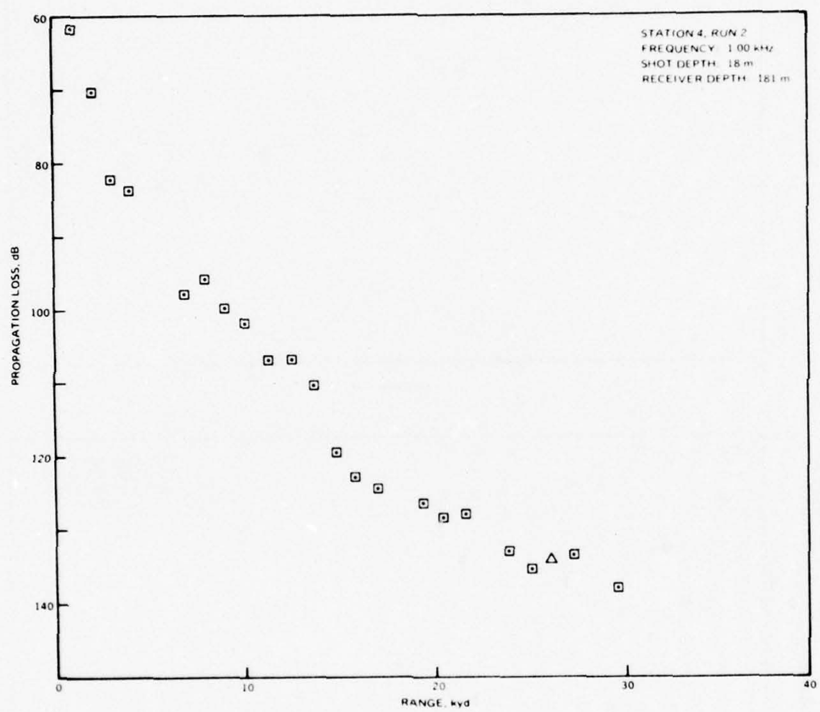

STATION 4, RUN 2
FREQUENCY: 0.63 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 181 m
PROPAGATION LOSS, dB
60
80
100
120
140
RANGE, kyd
0
10
20
30
40

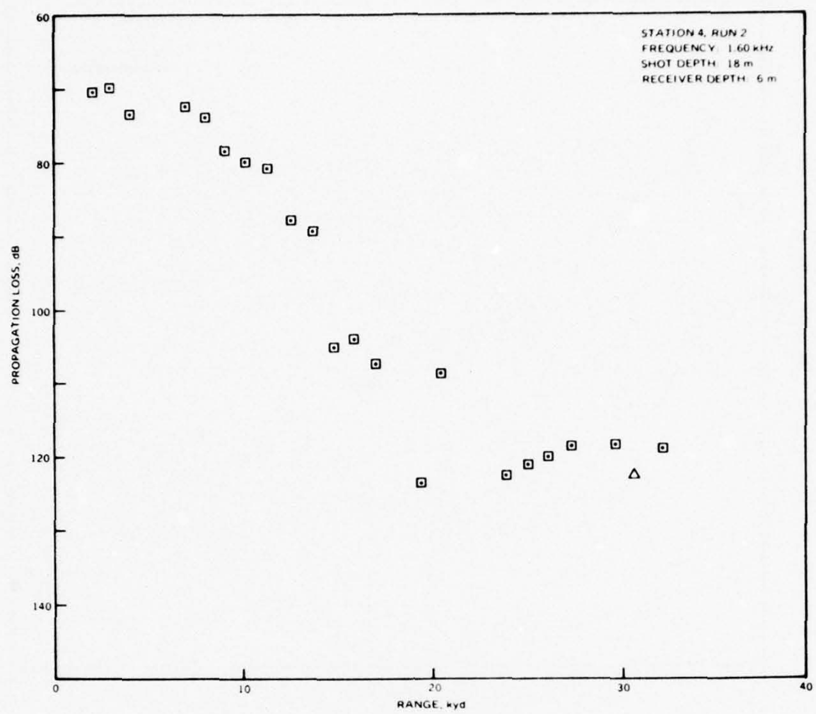

STATION 4, RUN 2
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd

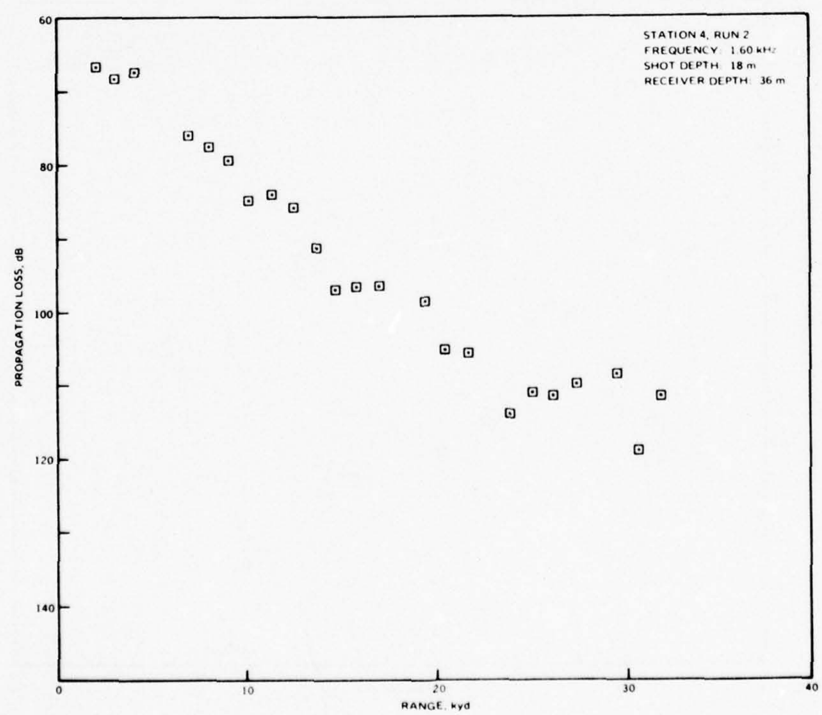

STATION 4, RUN 2
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 36 m
PROPAGATION LOSS, dB
RANGE, kyd

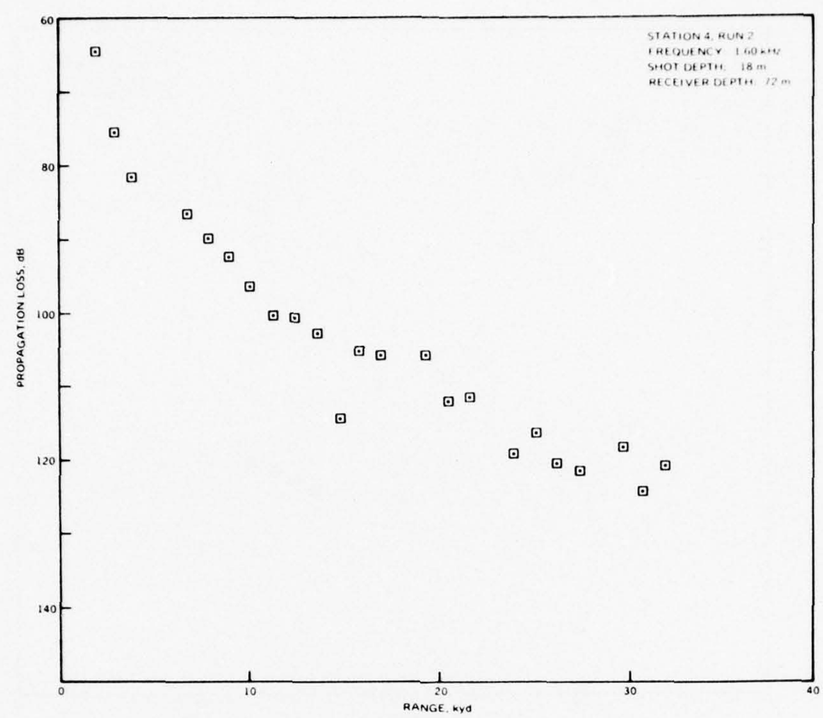

STATION 4, RUN 2
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 72 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

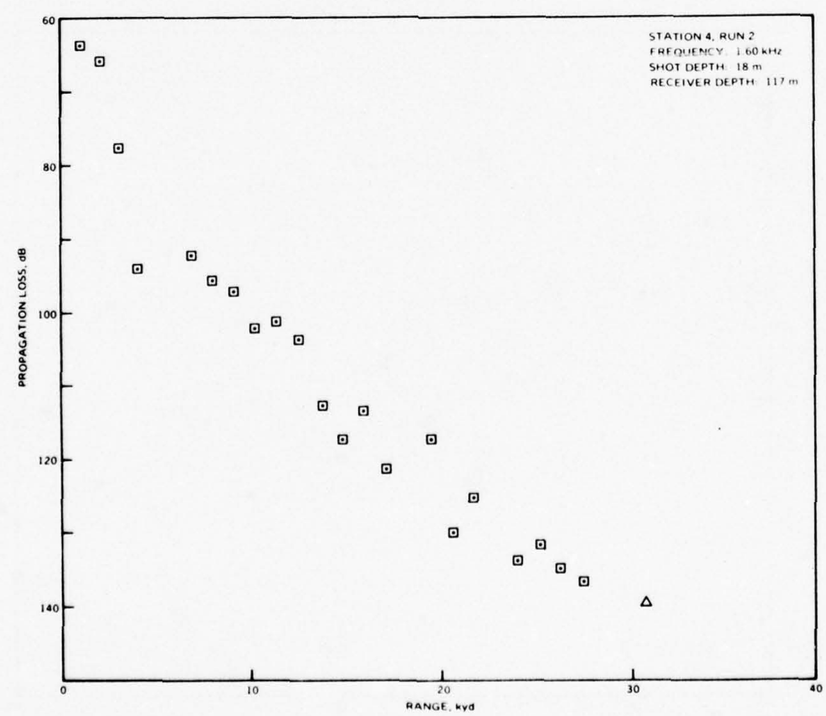

STATION 4, RUN 2
FREQUENCY: 1.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 117 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

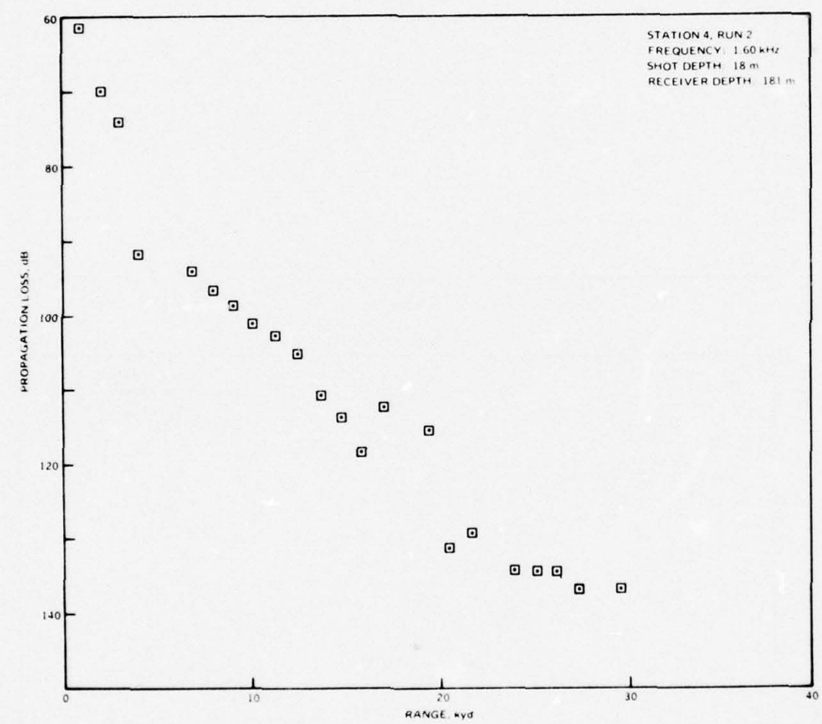

STATION 4, RUN 2
FREQUENCY 1.00 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 181 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd


STATION 4, RUN 2
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd

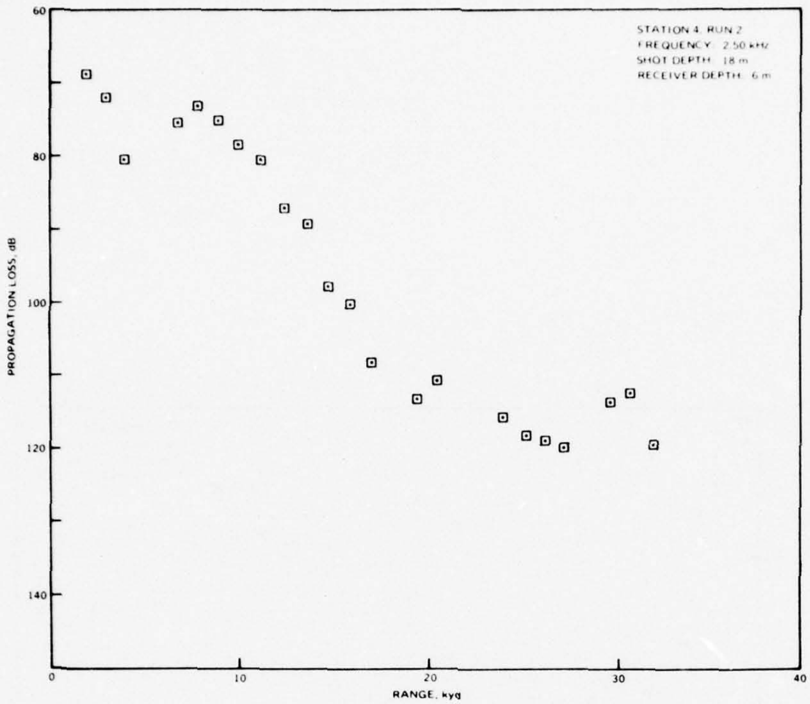

STATION 4, RUN 2
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 36 m
PROPAGATION LOSS, dB
RANGE, kyd

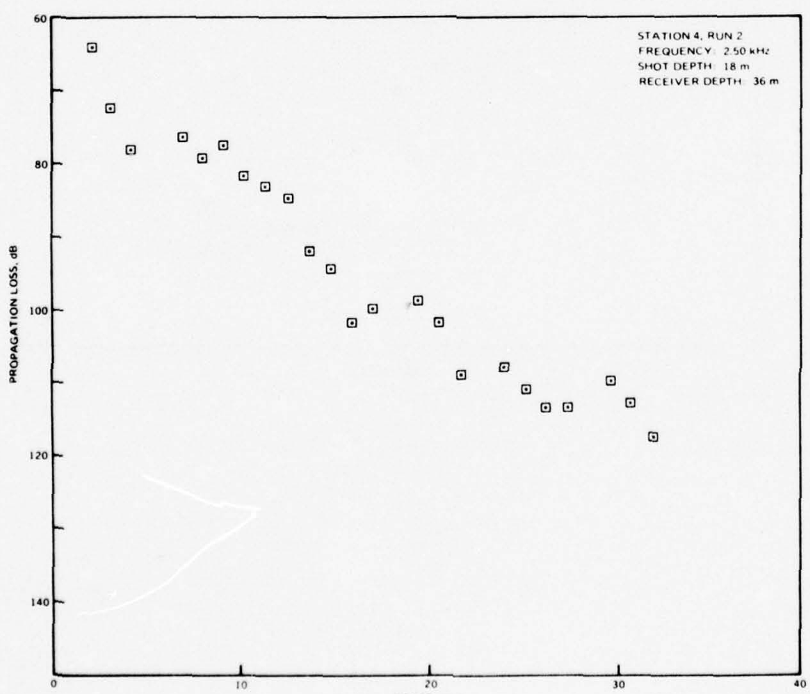

STATION 4, RUN 2
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 72 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

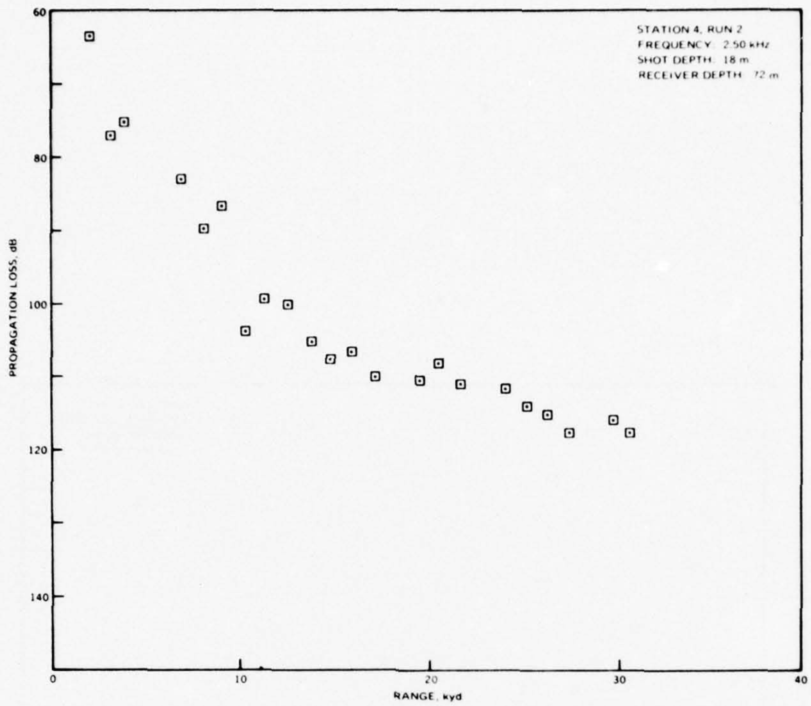

STATION 4, RUN 2
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 117 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

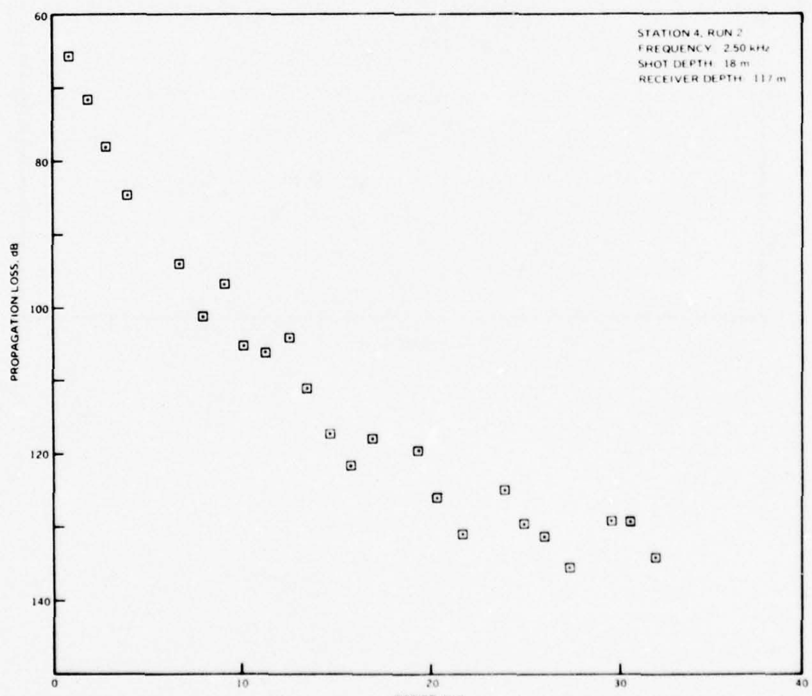


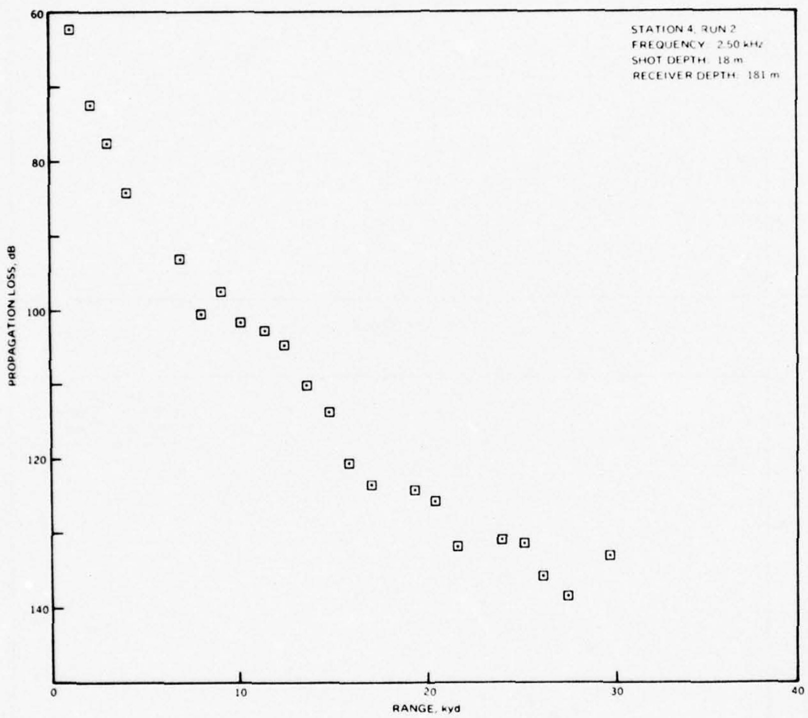
STATION 4, RUN 2
FREQUENCY: 1.60 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 181 m
PROPAGATION LOSS, dB
60
80
100
120
140
RANGE, kyd
0
10
20
30
40

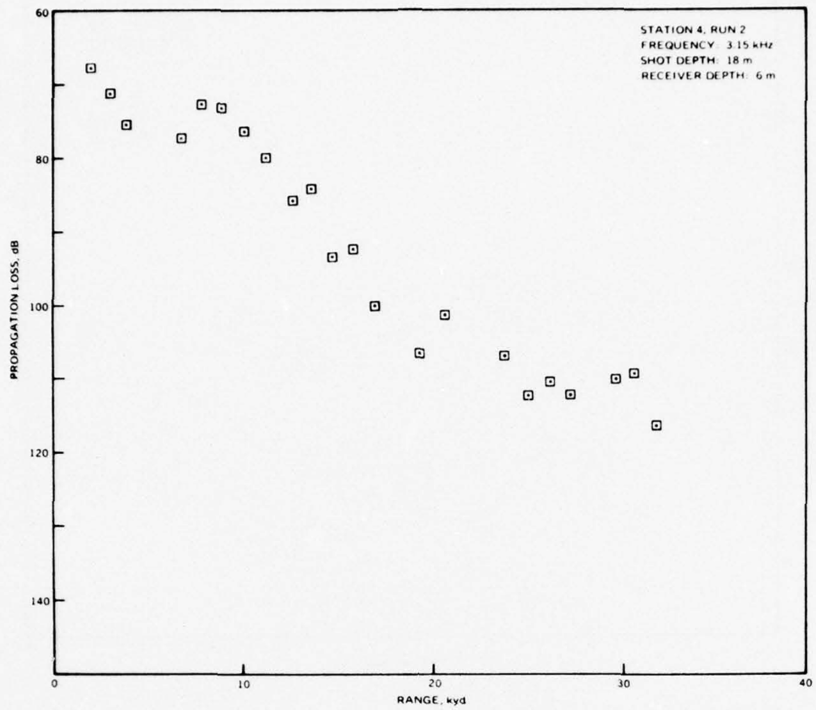

STATION 4, RUN 2
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

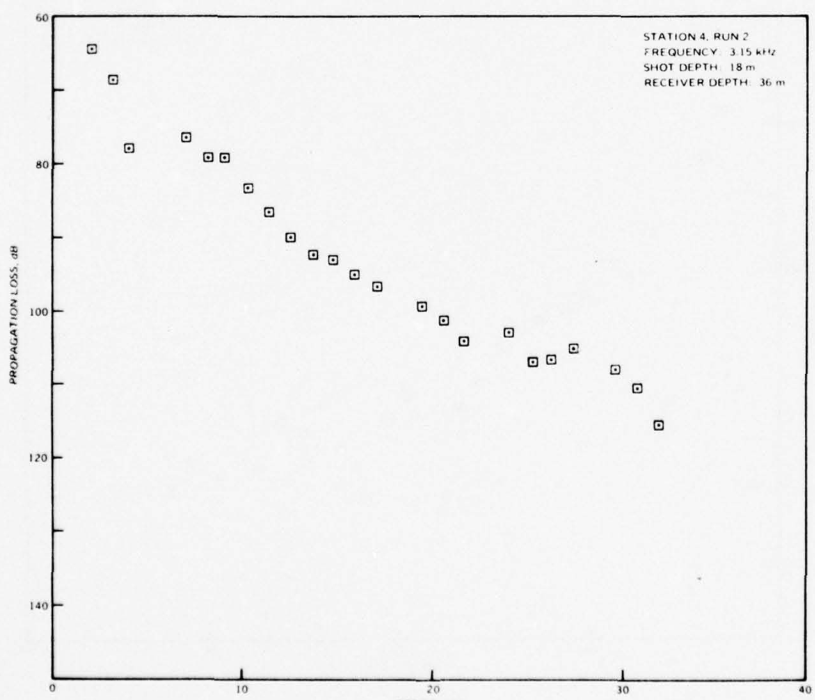

STATION 4, RUN 2
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 36 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

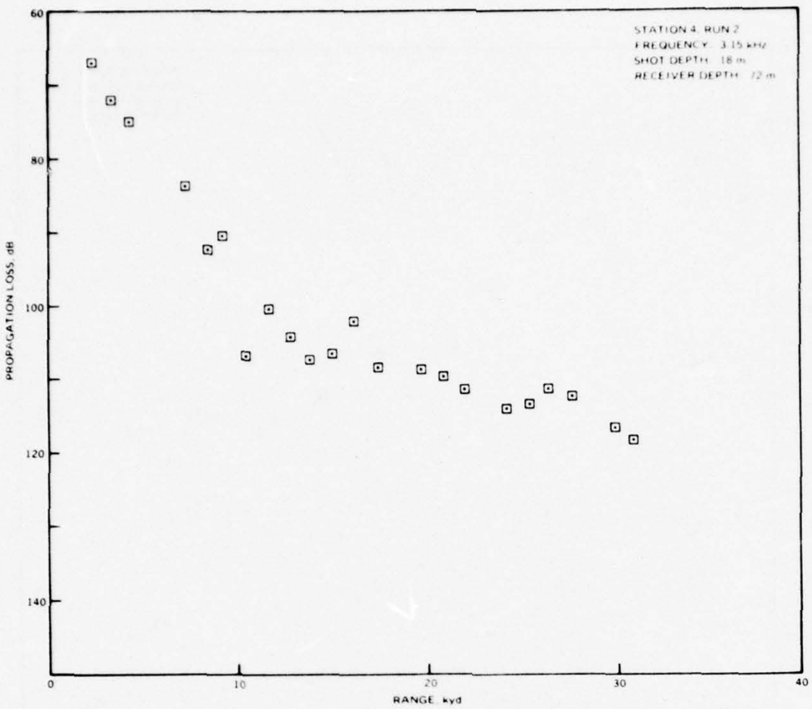

STATION 4, RUN 2
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 72 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

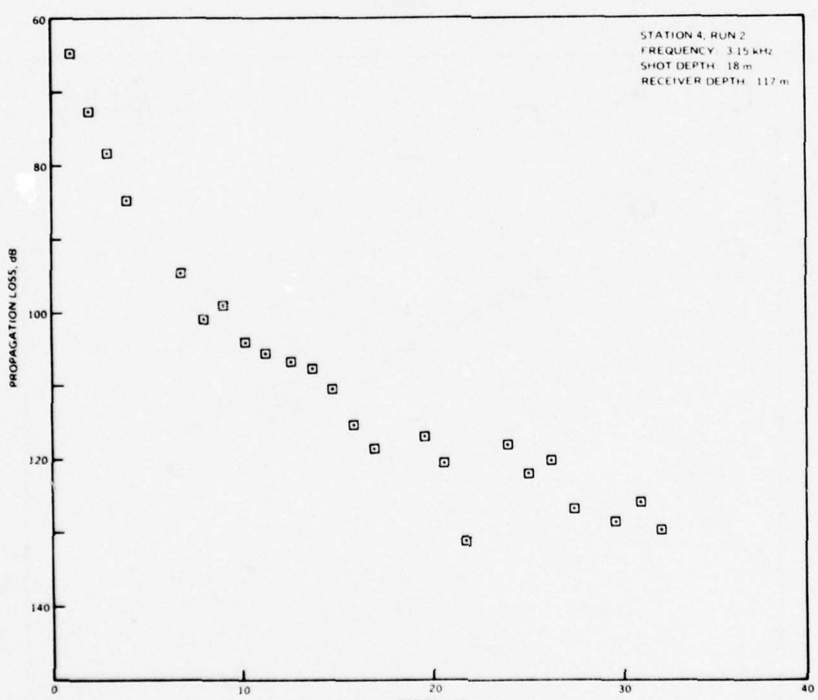

STATION 4, RUN 2
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 117 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

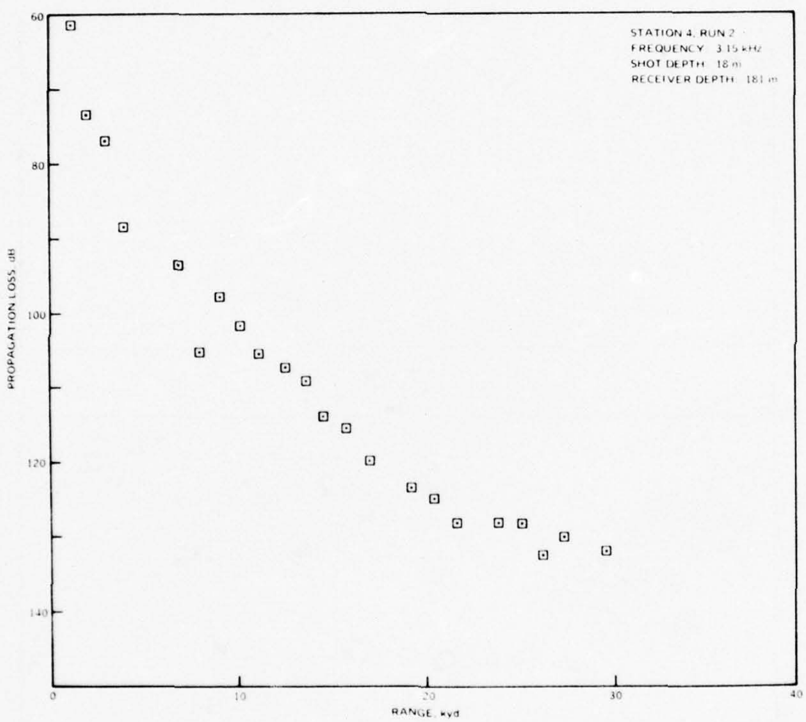

STATION 4, RUN 2
FREQUENCY: 2.50 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 181 m
PROPAGATION LOSS, dB
60
80
100
120
140
RANGE, kyd
0
10
20
30
40

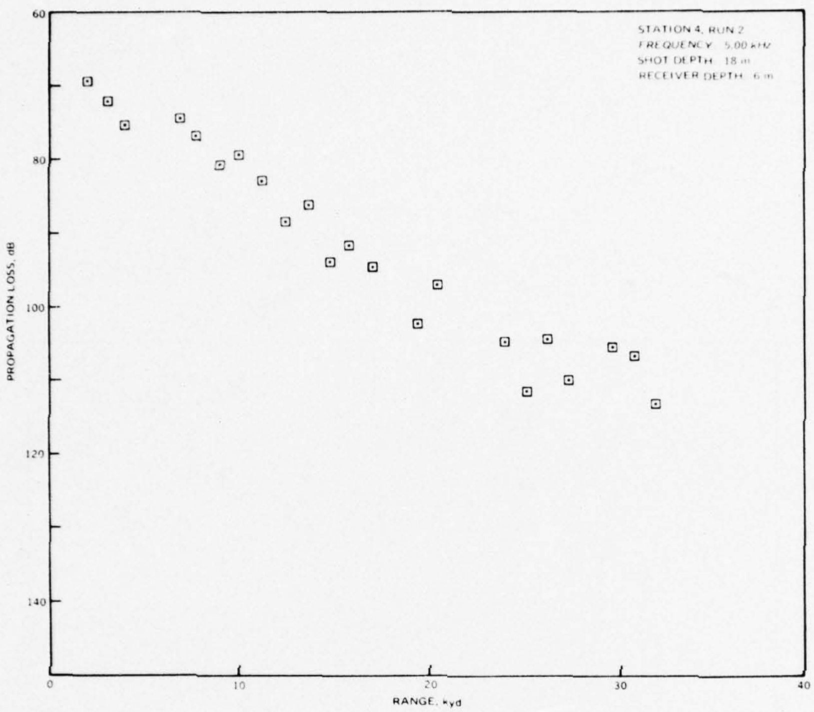

STATION 4, RUN 2
FREQUENCY: 3.15 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40


STATION 4, RUN 2
FREQUENCY: 3.15 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 36 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40

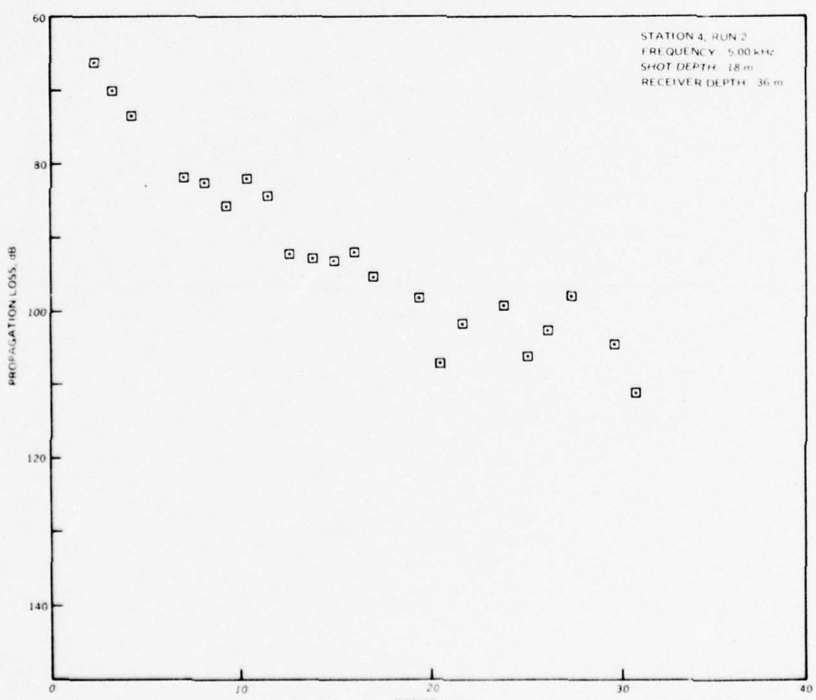

STATION 4, RUN 2
FREQUENCY: 3.15 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 72 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd


STATION 4, RUN 2
FREQUENCY: 3.15 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 117 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

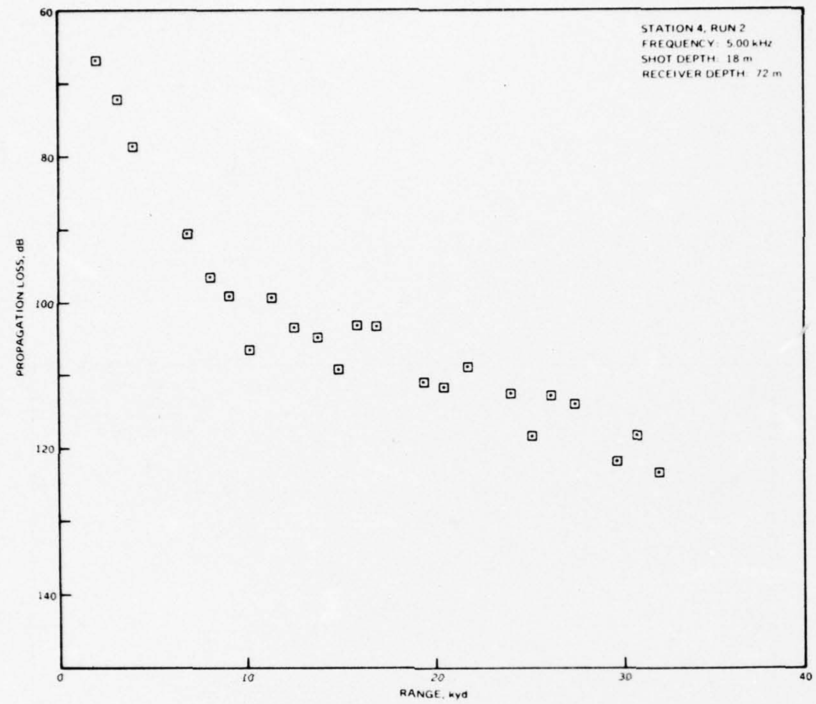

STATION 4, RUN 2
FREQUENCY: 3.15 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 181 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

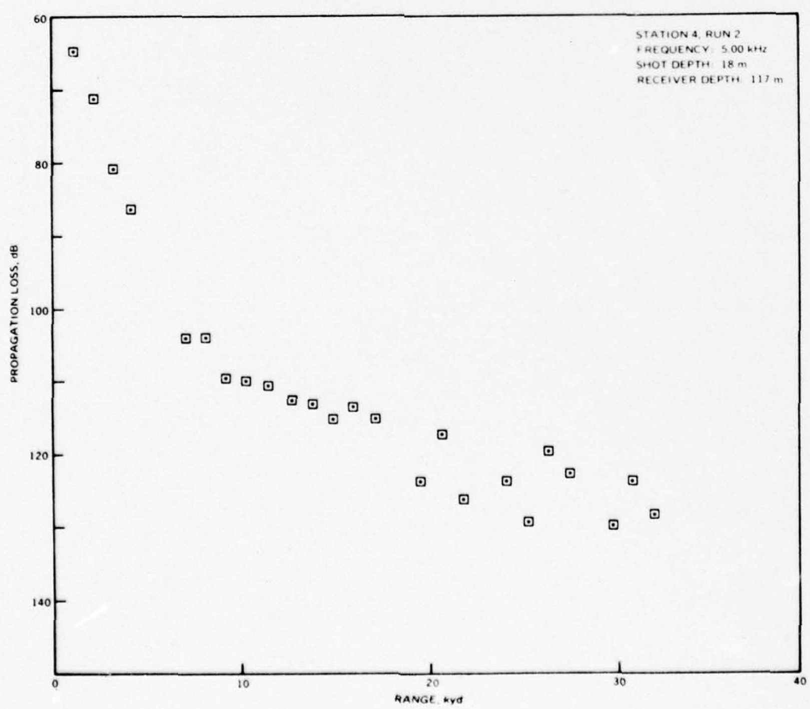


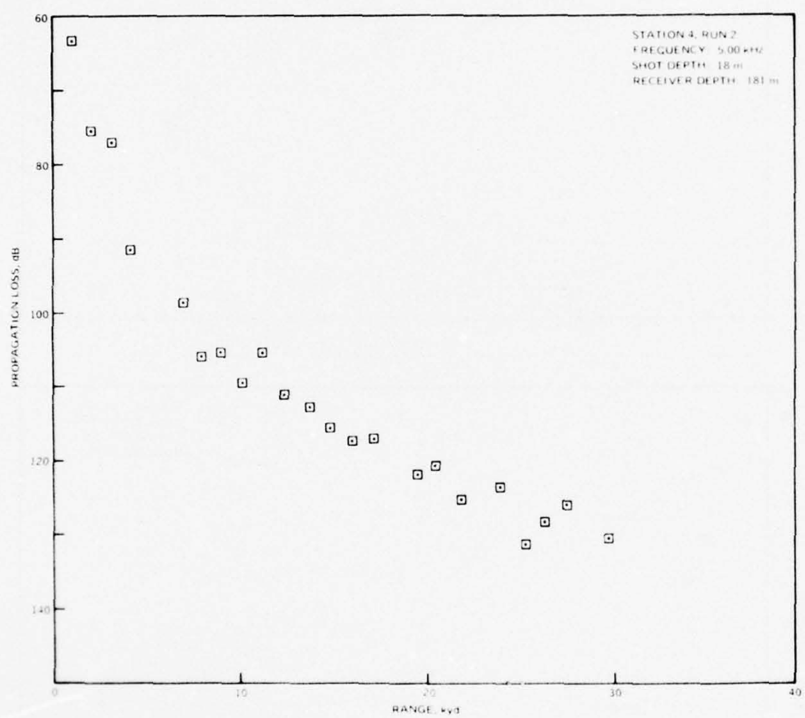
STATION 4, RUN 2
FREQUENCY 5.00 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 6 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

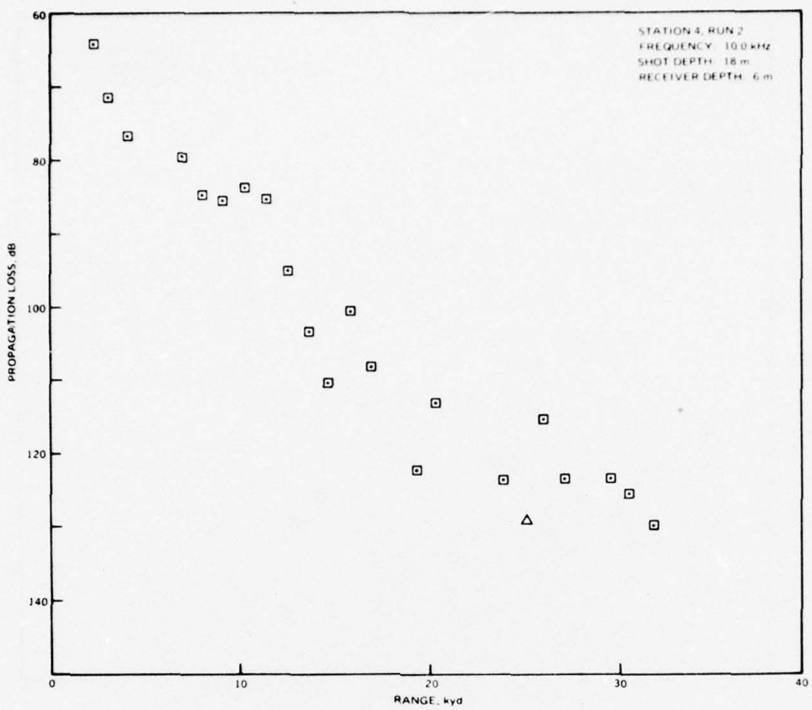


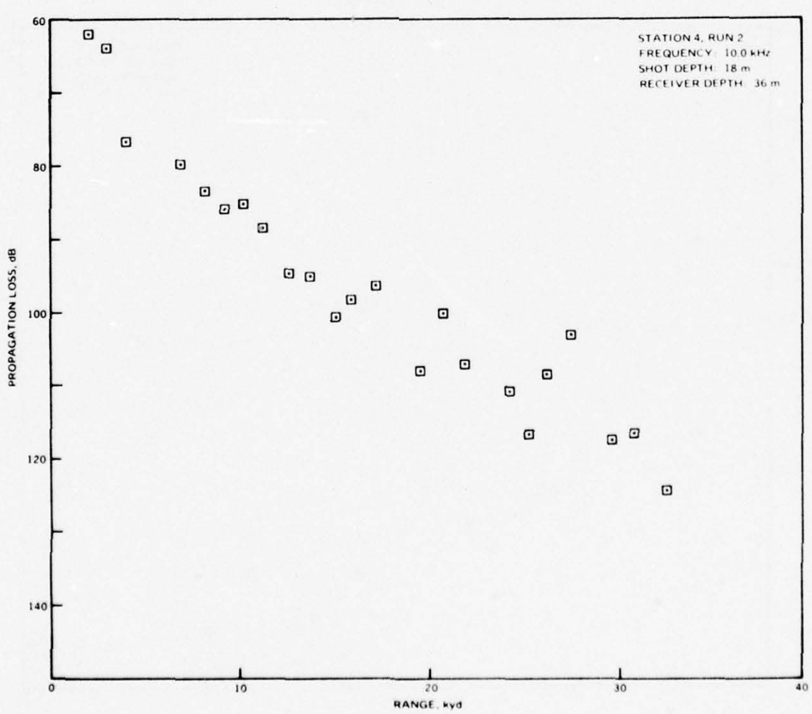
STATION 4, RUN 2
FREQUENCY 5.00 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 36 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

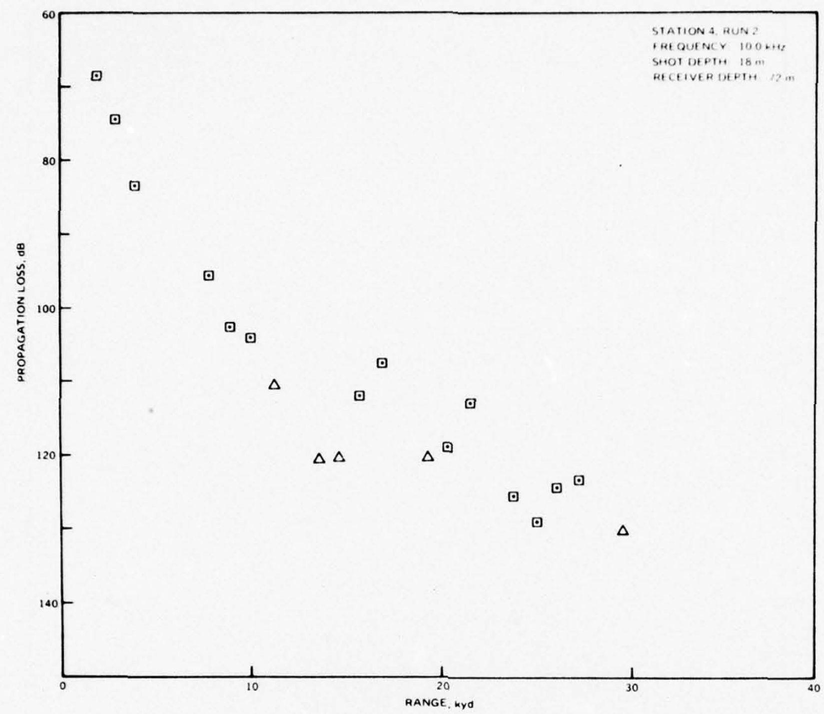

STATION 4, RUN 2
FREQUENCY: 5.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 72 m
PROPAGATION LOSS, dB
RANGE, kyd

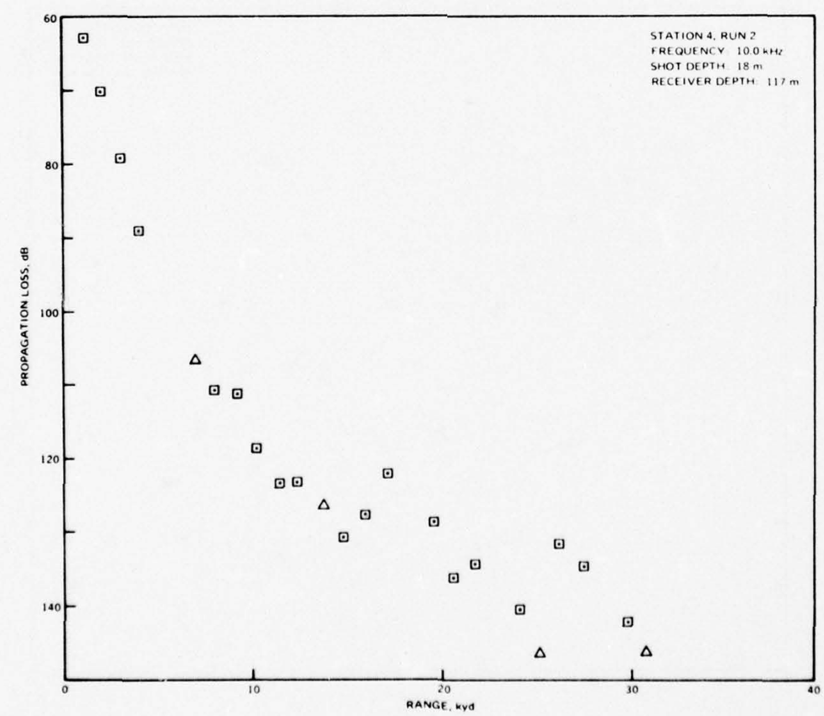

STATION 4, RUN 2
FREQUENCY: 5.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 117 m
PROPAGATION LOSS, dB
RANGE, kyd

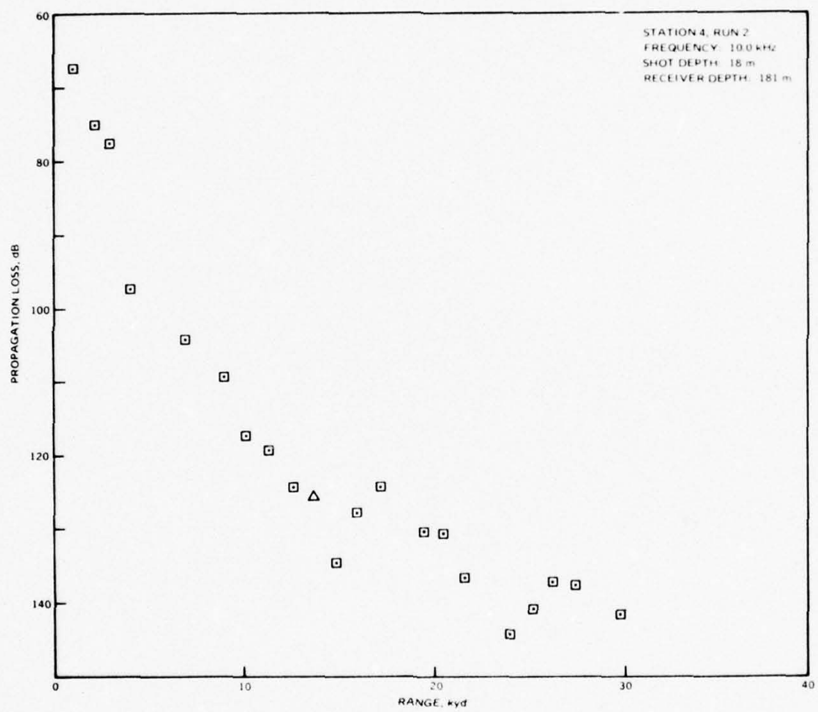

STATION 4, RUN 2
FREQUENCY: 5.00 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 181 m
60
80
100
120
140
PROPAGATION LOSS, dB
0
10
20
30
40
RANGE, kyd


STATION 4, RUN 2
FREQUENCY: 10.0 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 6 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40


STATION 4, RUN 2
FREQUENCY: 10.0 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 36 m
PROPAGATION LOSS, dB
RANGE, kyd
60
80
100
120
140
0
10
20
30
40


STATION 4, RUN 2
FREQUENCY 10.0 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 72 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

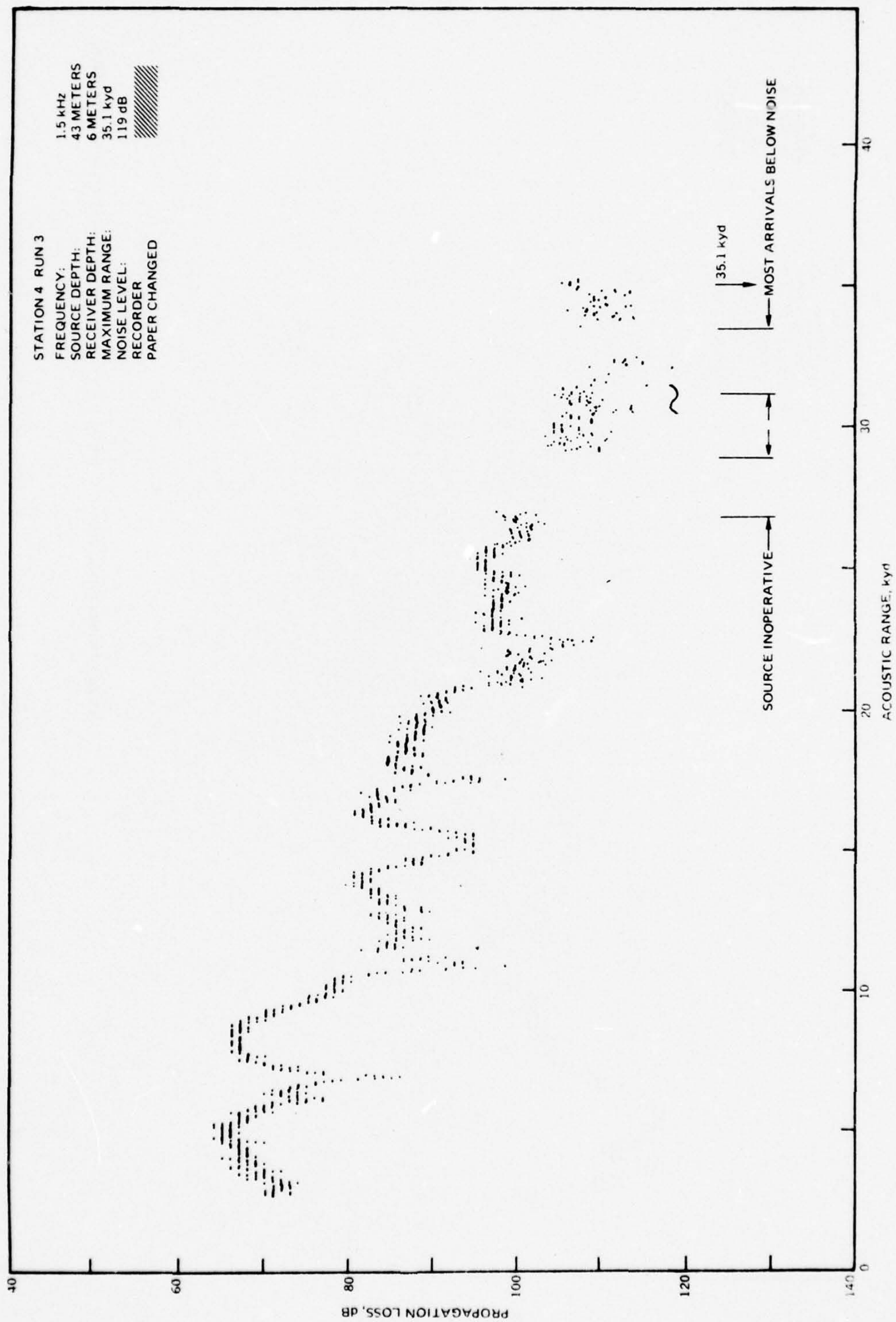

STATION 4, RUN 2
FREQUENCY 10.0 kHz
SHOT DEPTH 18 m
RECEIVER DEPTH 117 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

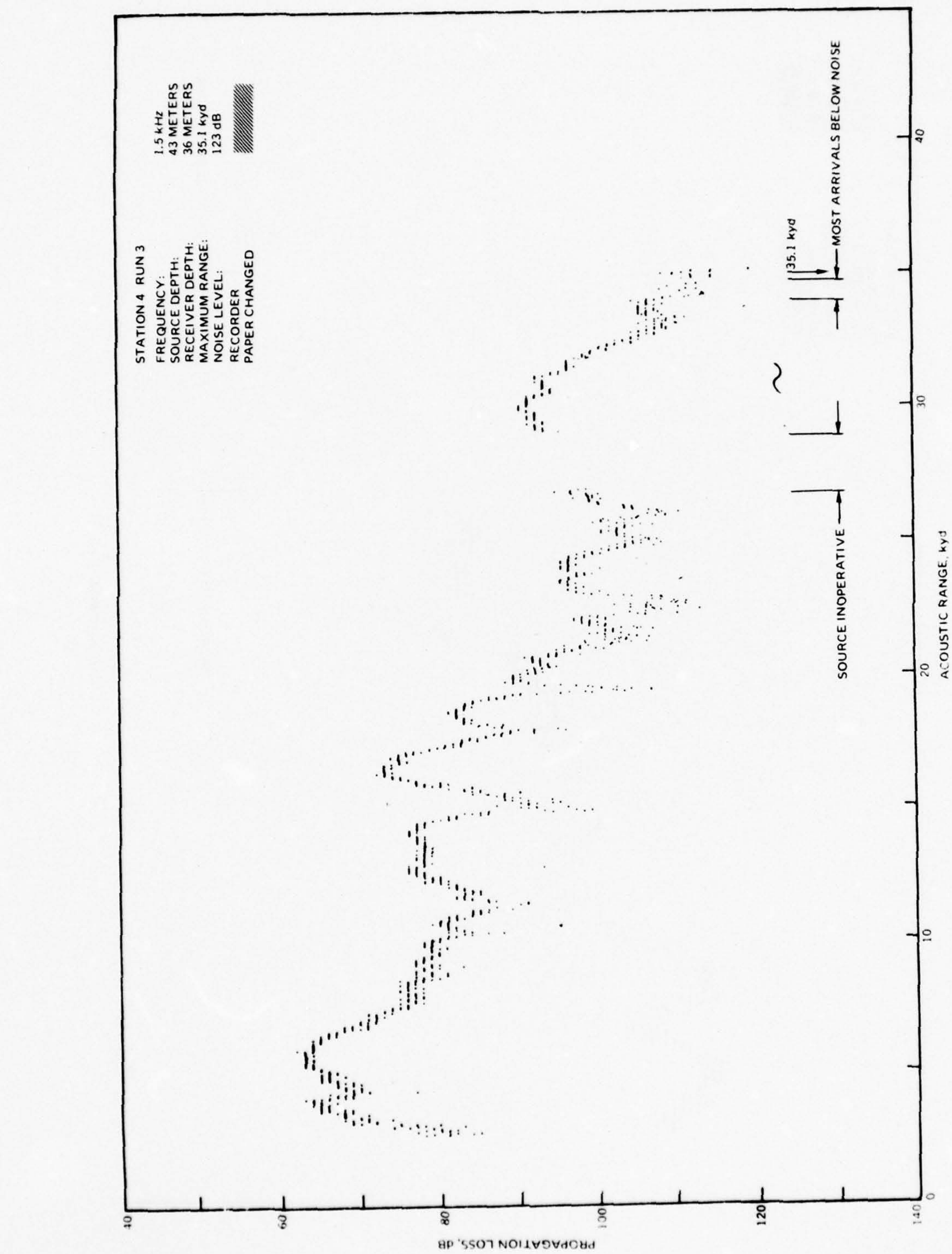

STATION 4, RUN 2
FREQUENCY: 10.0 kHz
SHOT DEPTH: 18 m
RECEIVER DEPTH: 181 m
PROPAGATION LOSS, dB
60
80
100
120
140
0
10
20
30
40
RANGE, kyd

APPENDIX C

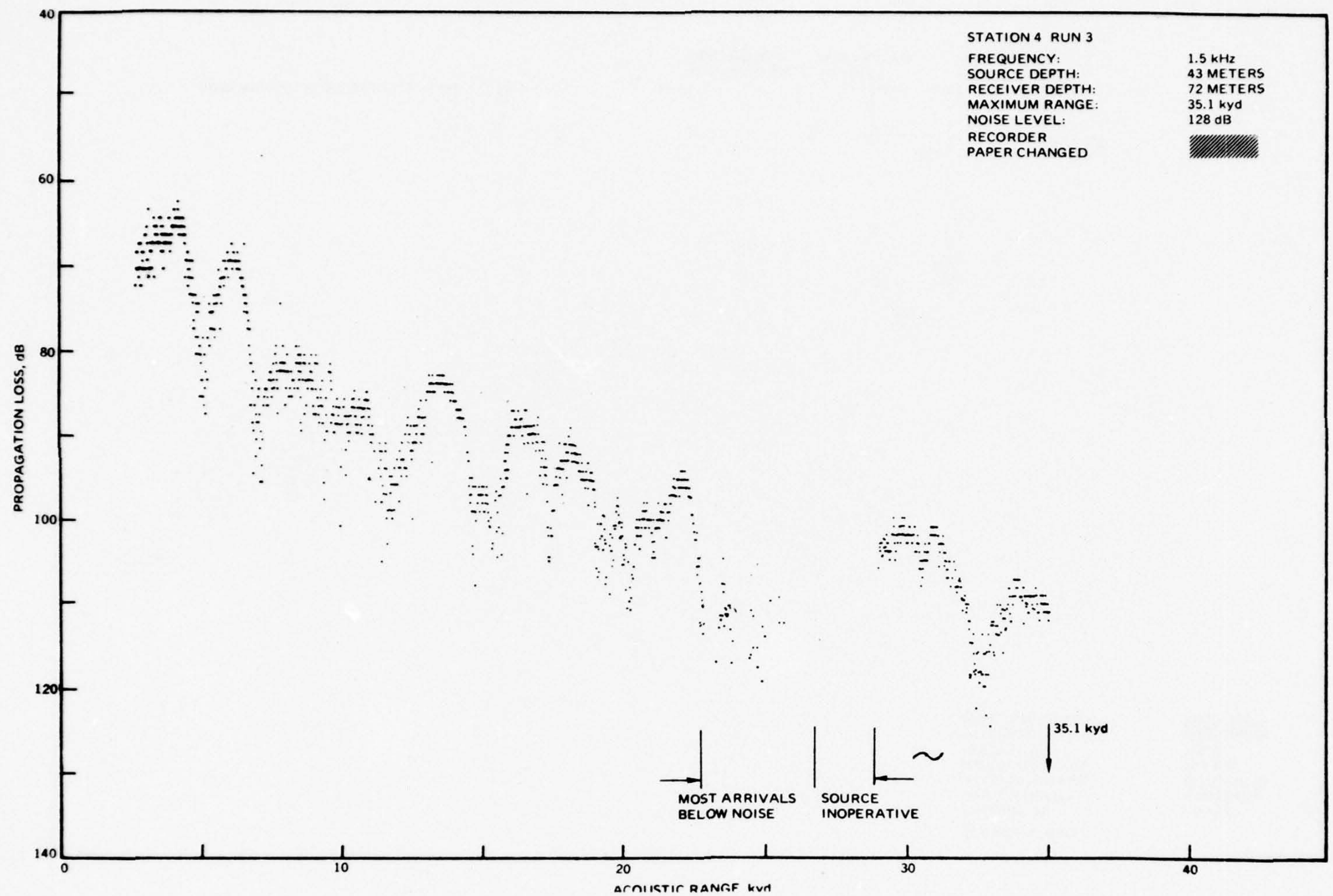
STATION 4 RUN 3

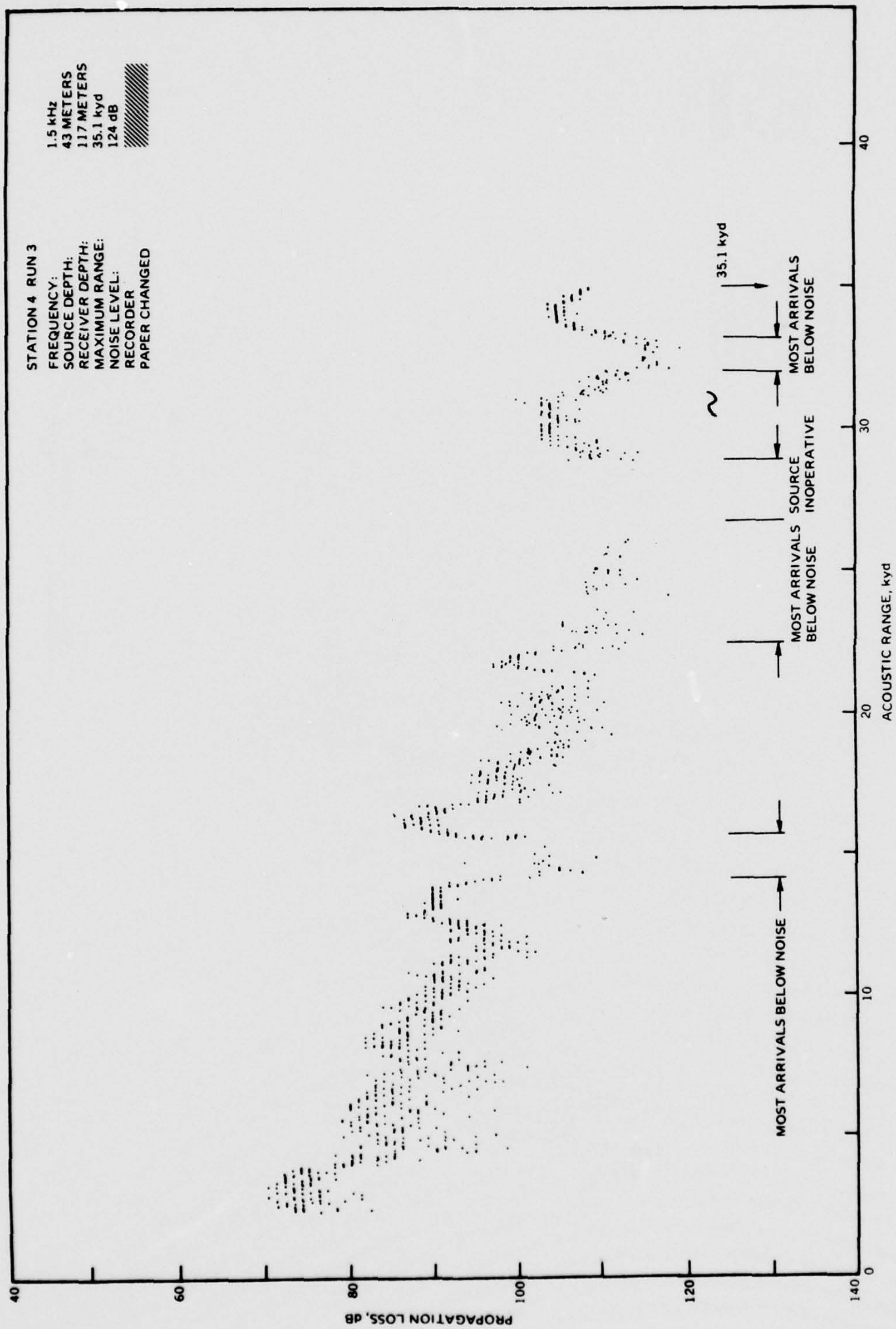
PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

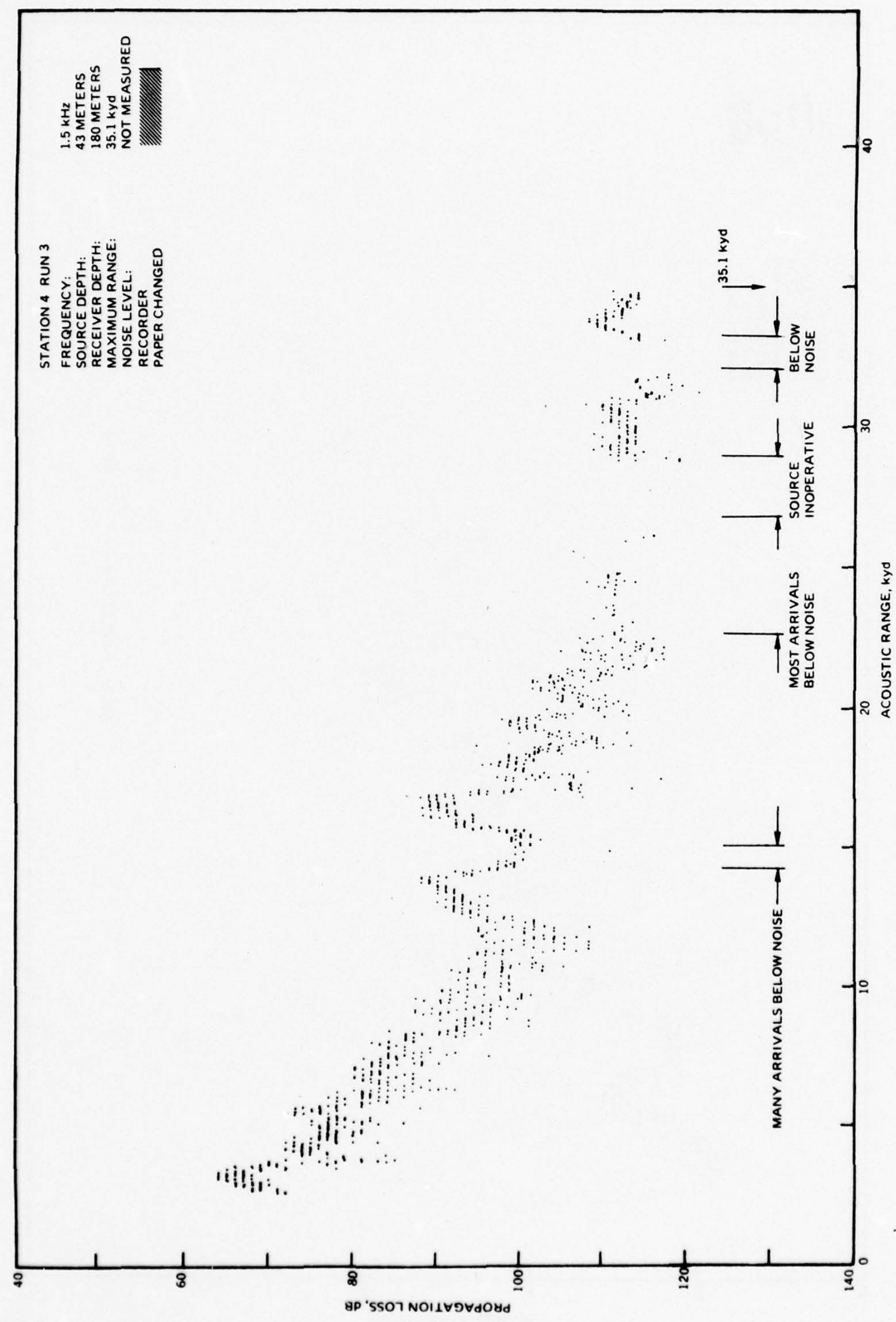

STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 119 dB
RECORDER
PAPER CHANGED
35.1 kyd
MOST ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
40
60
80
100
120
140

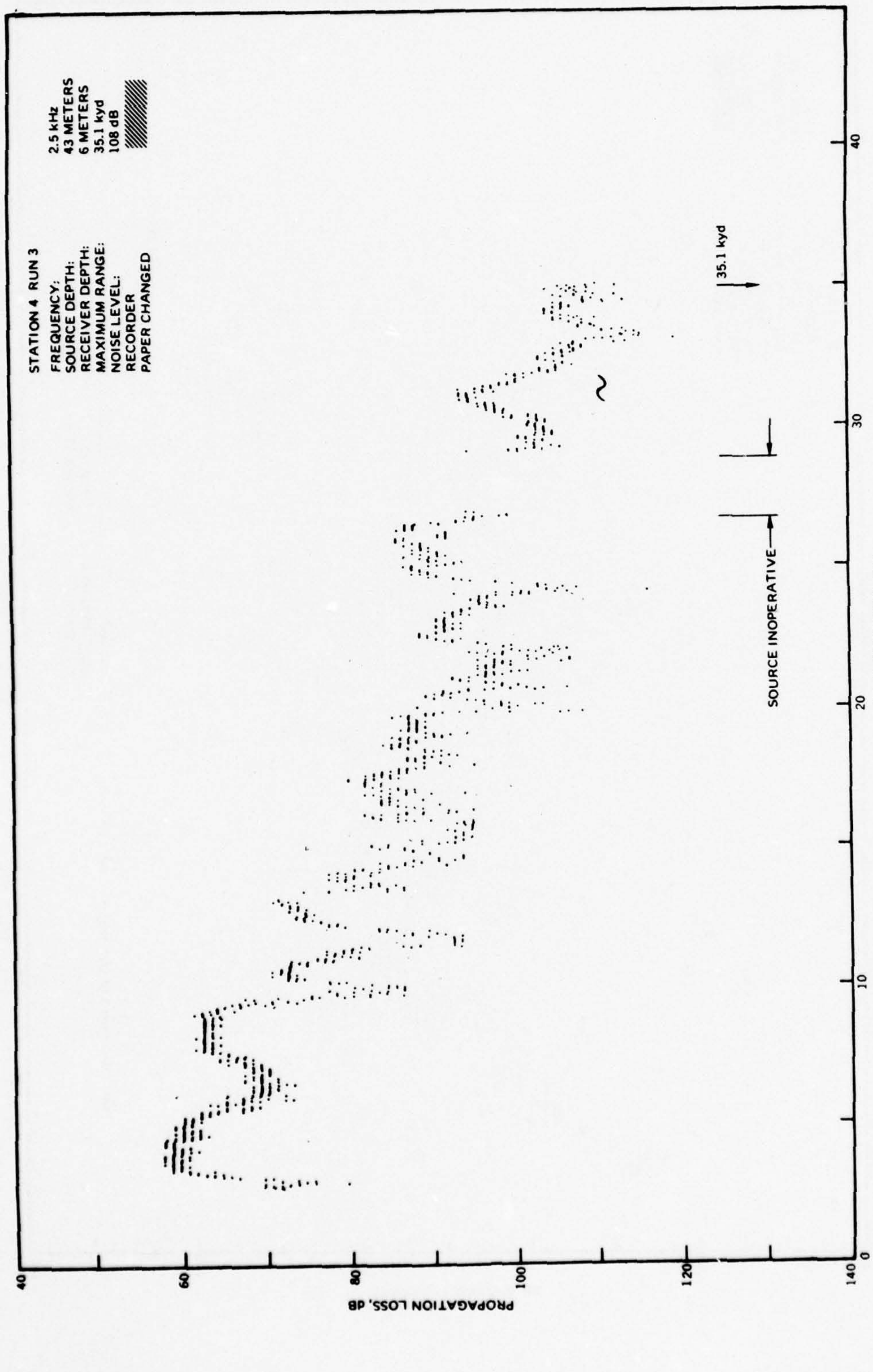


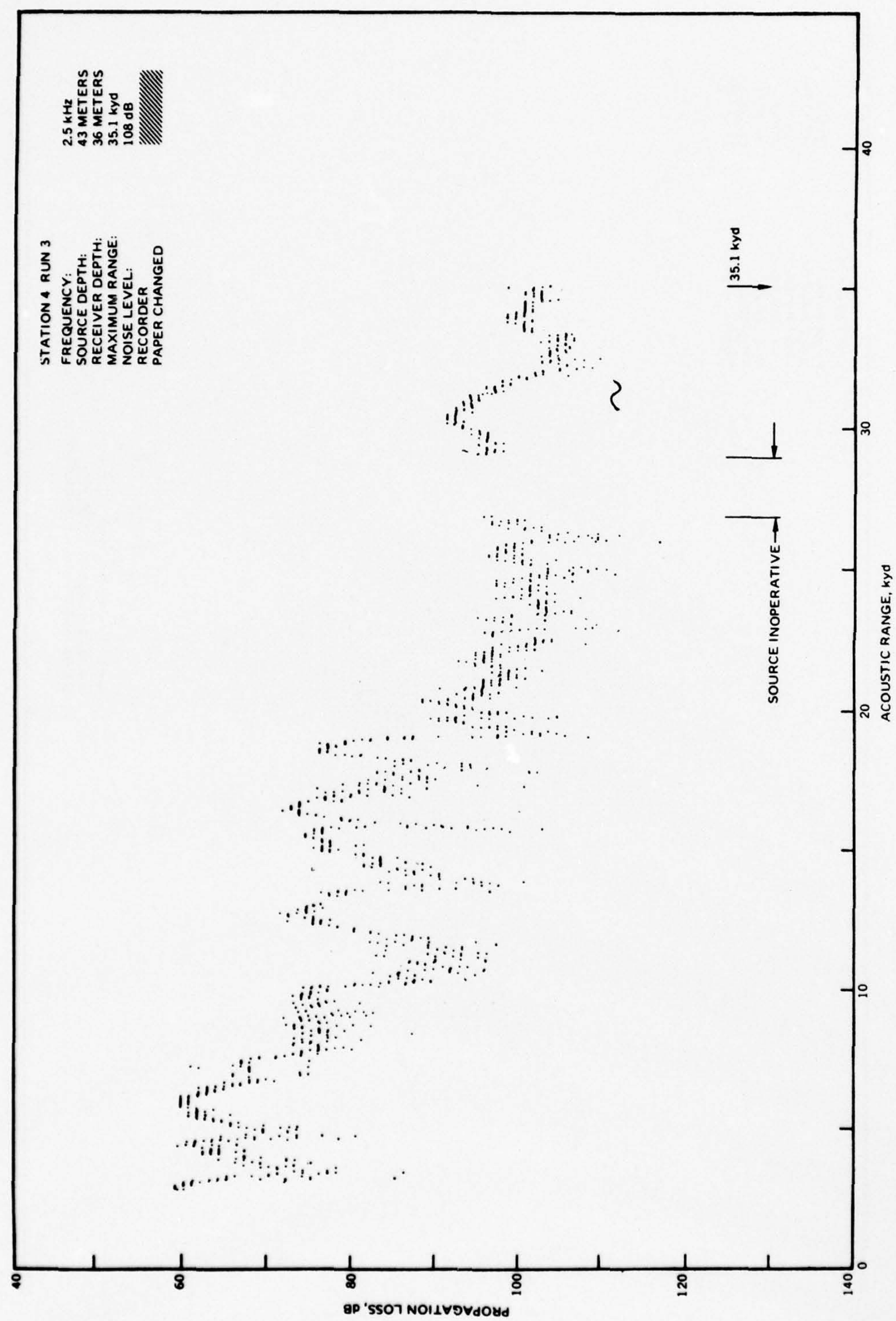
STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 123 dB
RECORDER PAPER CHANGED
35.1 kyd
MOST ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
60
80
100
120
140

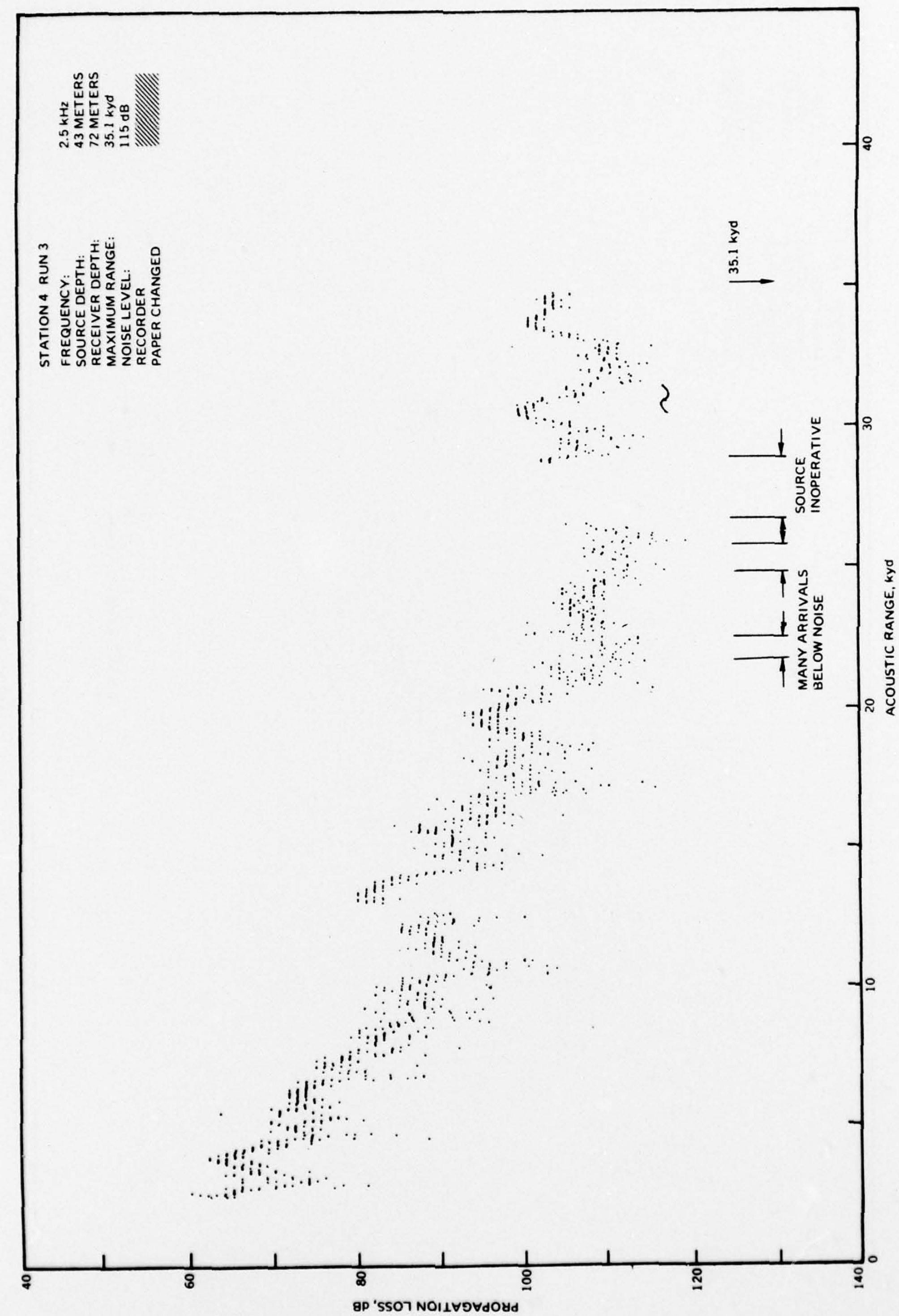

STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 128 dB
RECORDER PAPER CHANGED
MOST ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
35.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

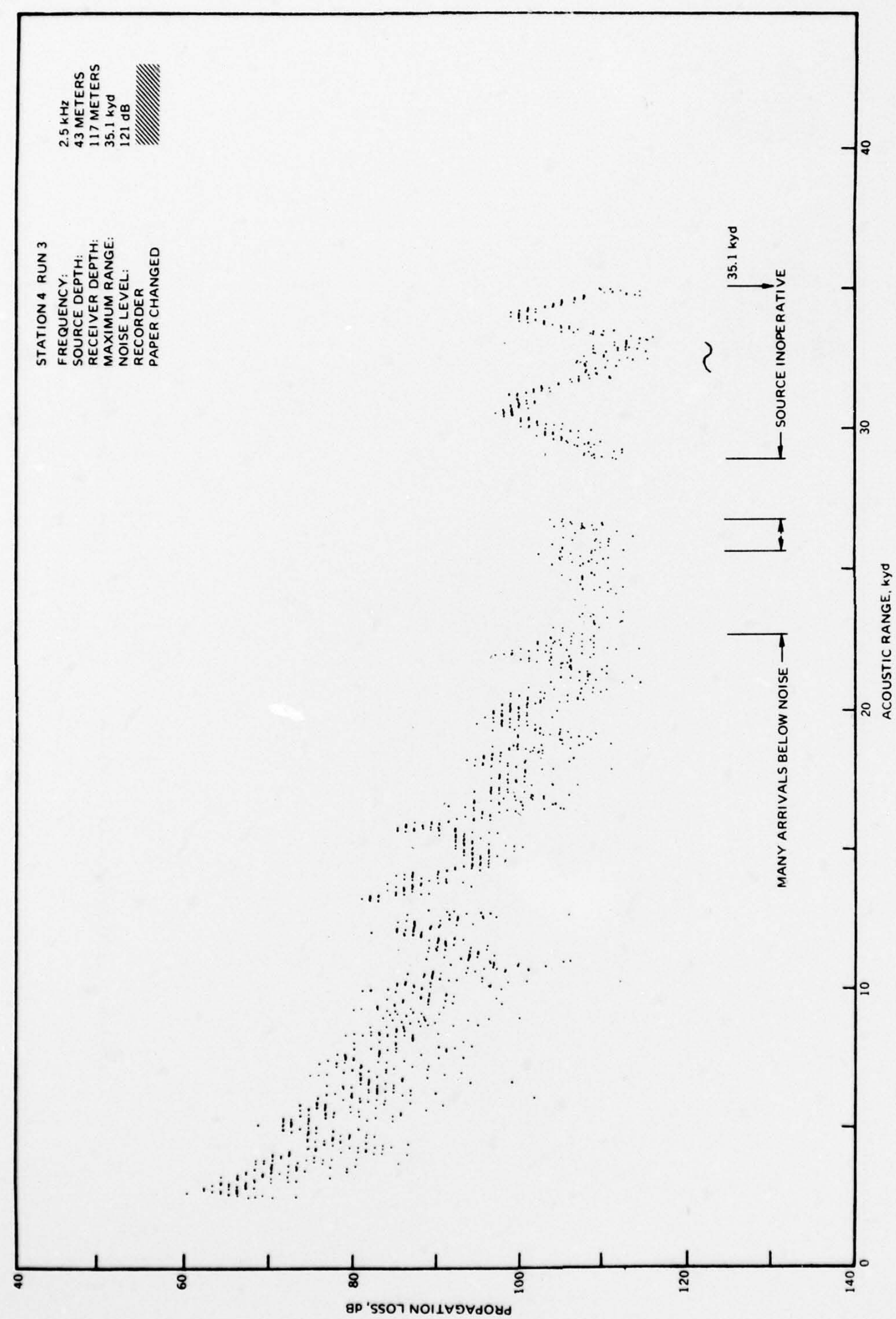

STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 117 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 124 dB
RECORDER PAPER CHANGED
35.1 kyd
MOST ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 180 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
35.1 kyd
BELOW NOISE
SOURCE INOPERATIVE
MOST ARRIVALS BELOW NOISE
MANY ARRIVALS BELOW NOISE
0
10
20
30
40
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
PROPAGATION LOSS, dB

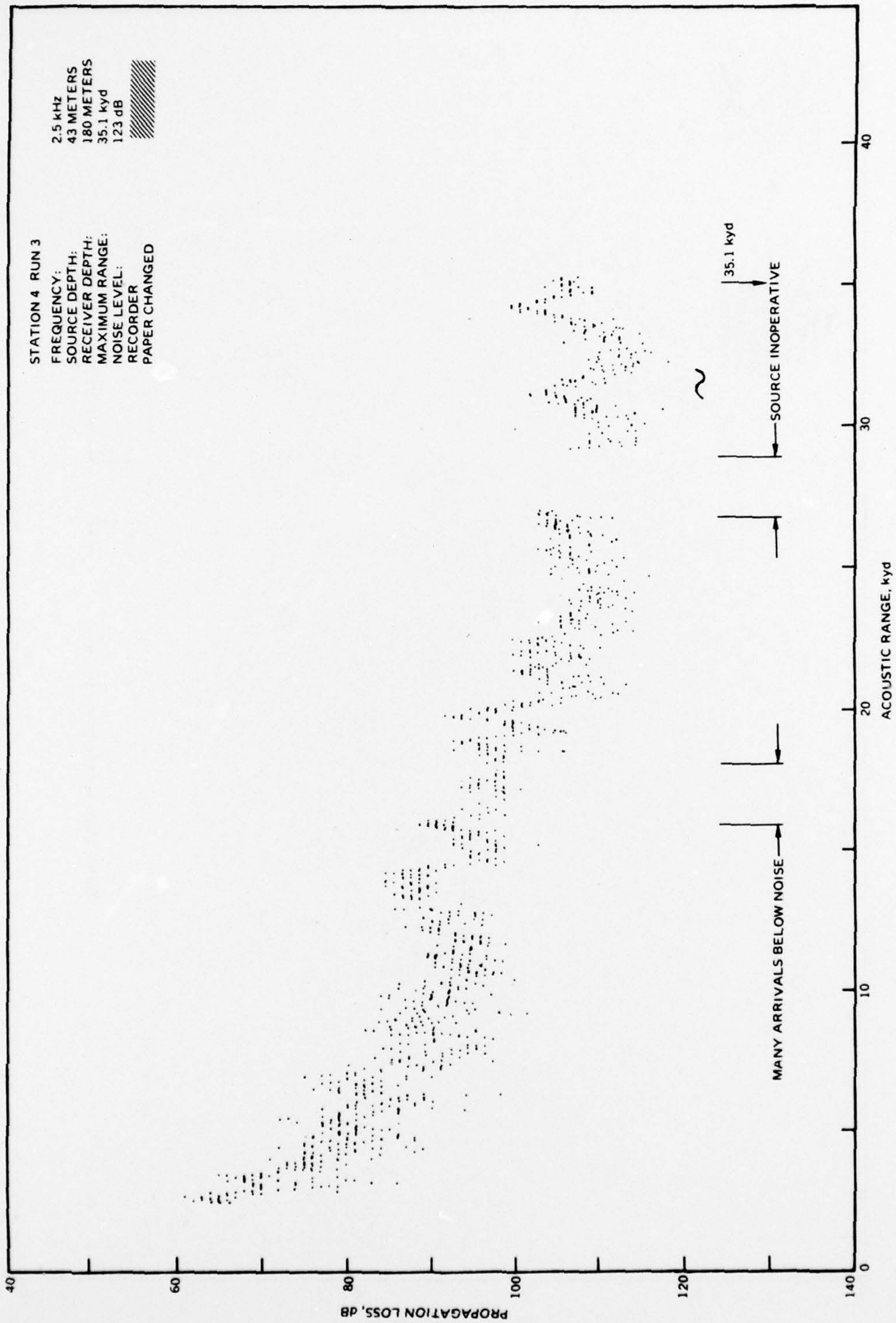

STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 108 dB
RECORDER PAPER CHANGED
35.1 kyd
SOURCE INOPERATIVE
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40


STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 108 dB
RECORDER PAPER CHANGED
SOURCE INOPERATIVE
35.1 kyd
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
40
60
80
100
120
140


STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 115 dB
RECORDER PAPER CHANGED
35.1 kyd
SOURCE INOPERATIVE
MANY ARRIVALS BELOW NOISE
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
60
80
100
120
140



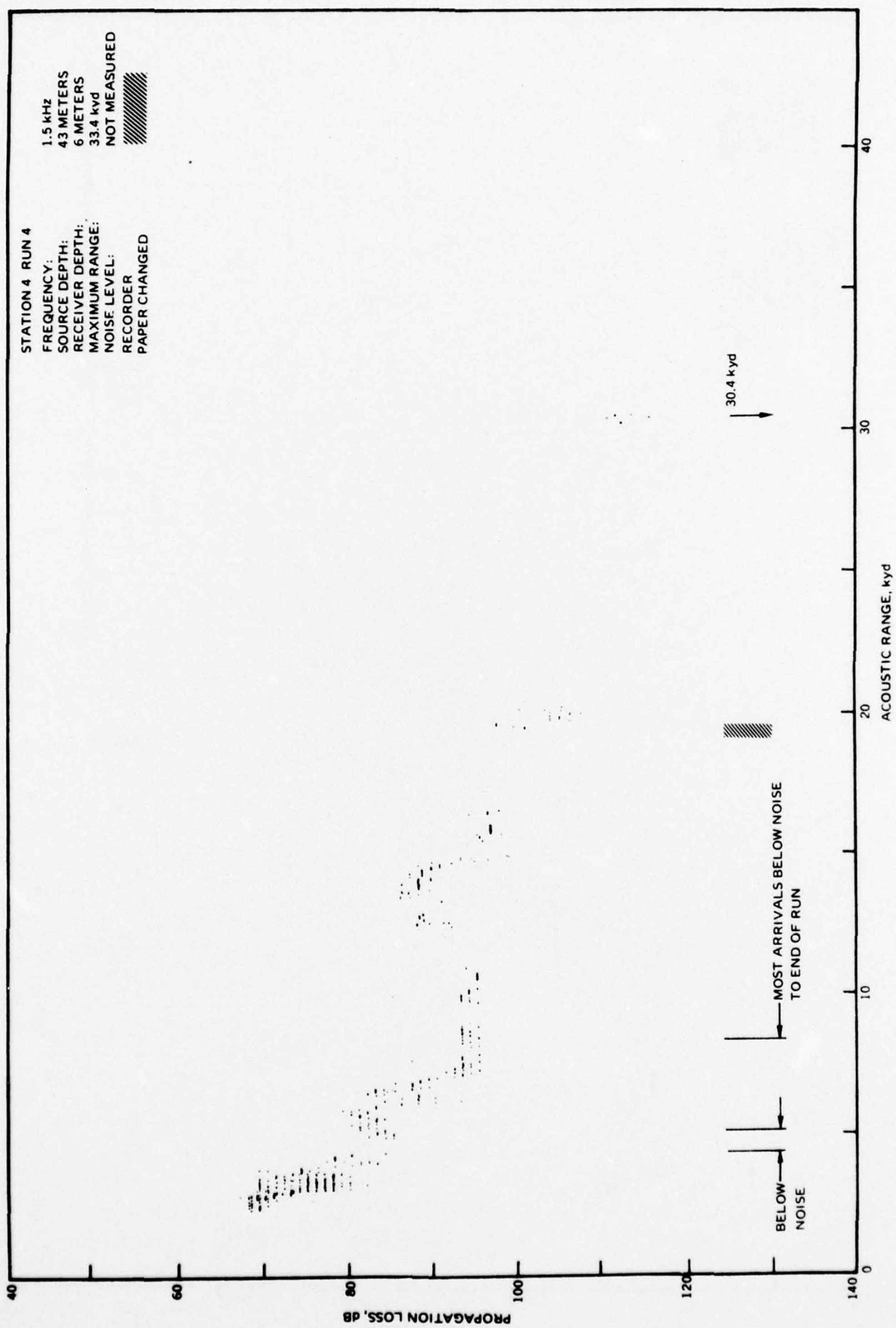
STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 117 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 121 dB
RECORDER PAPER CHANGED
35.1 kyd
SOURCE INOPERATIVE
MANY ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40

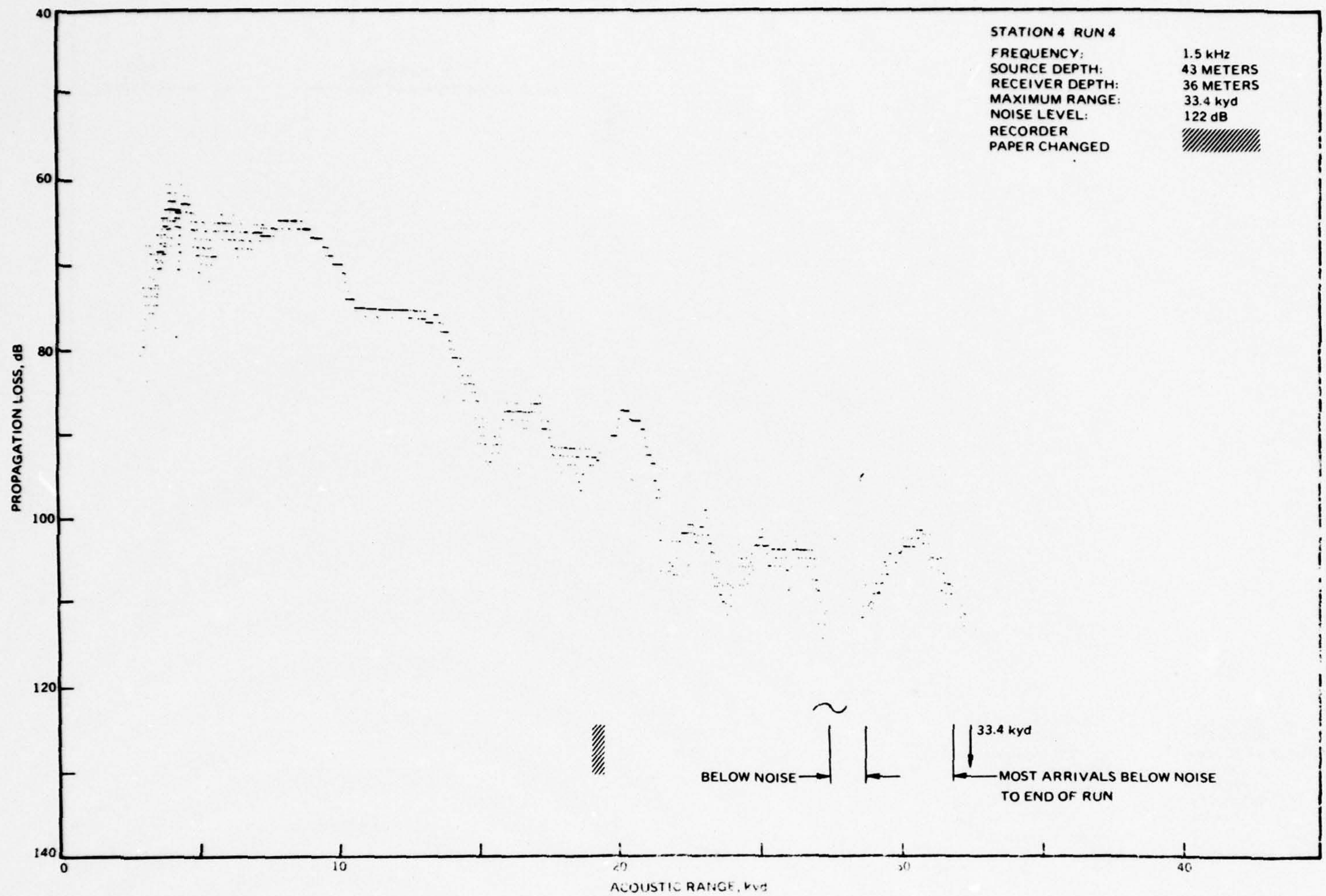

STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 180 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 123 dB
RECORDER PAPER CHANGED
35.1 kyd
SOURCE INOPERATIVE
MANY ARRIVALS BELOW NOISE
ACOUSTIC RANGE, kyd
0
10
20
30
40
PROPAGATION LOSS, dB
40
60
80
100
120
140

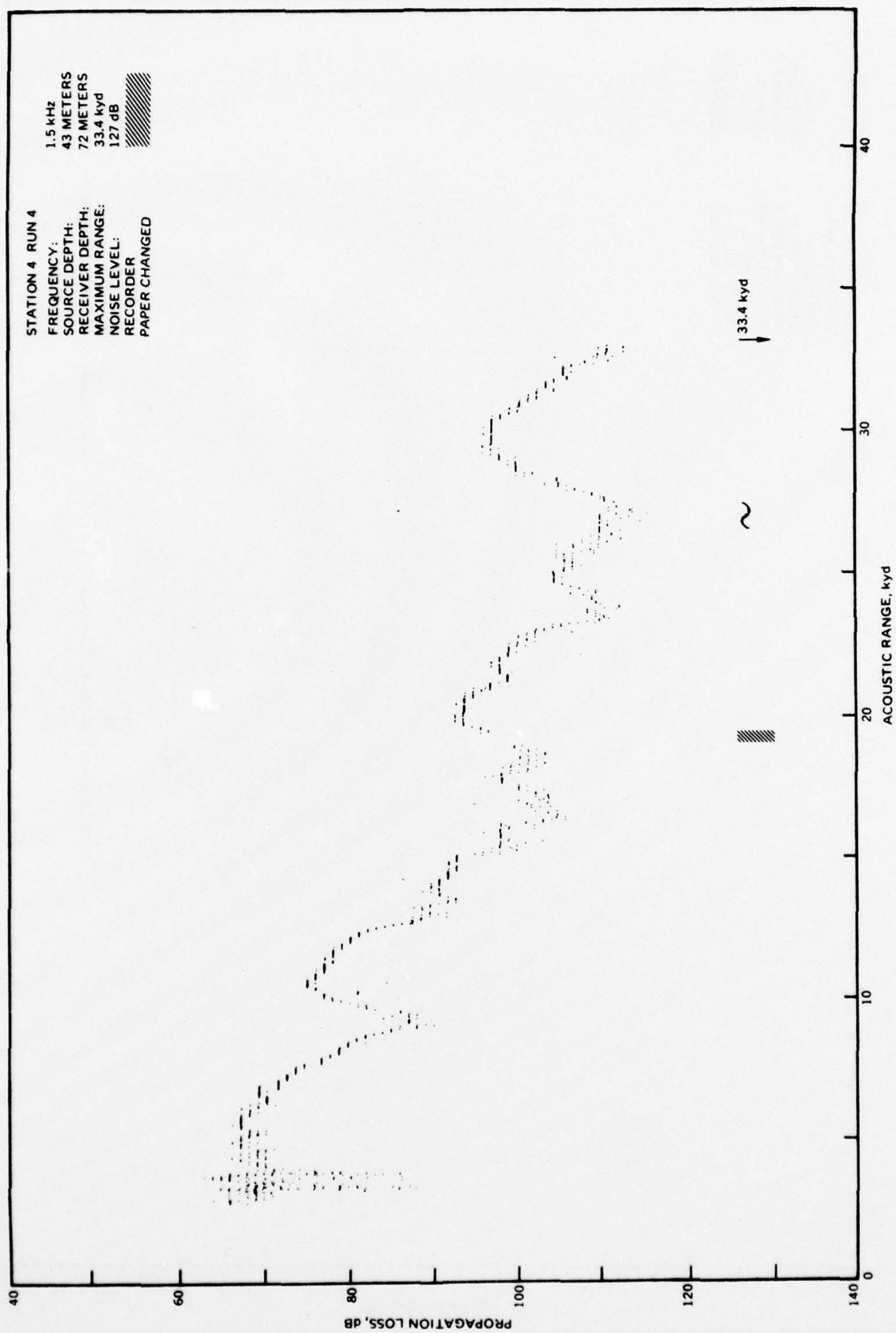
APPENDIX D

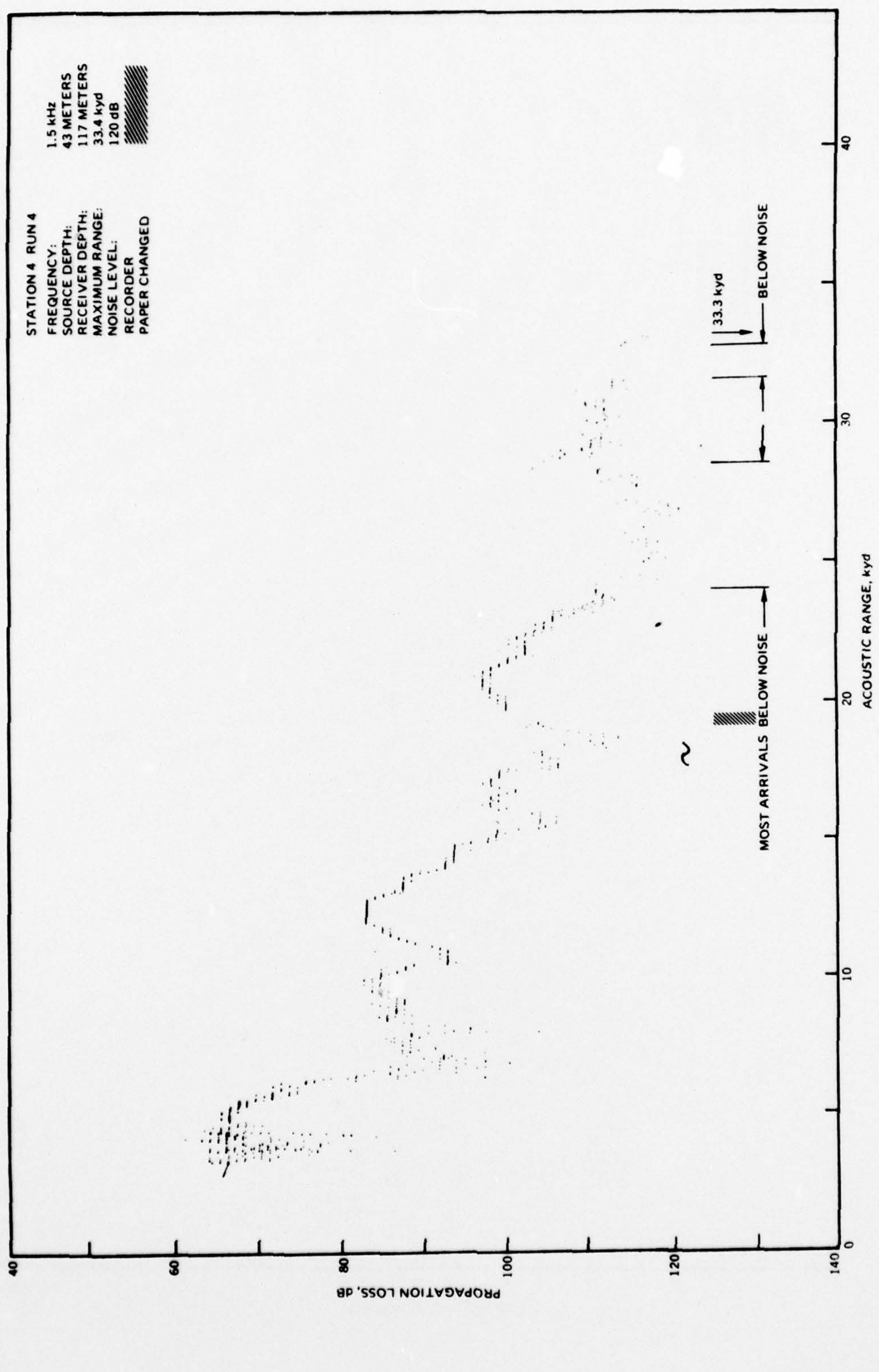
STATION 4 RUN 4

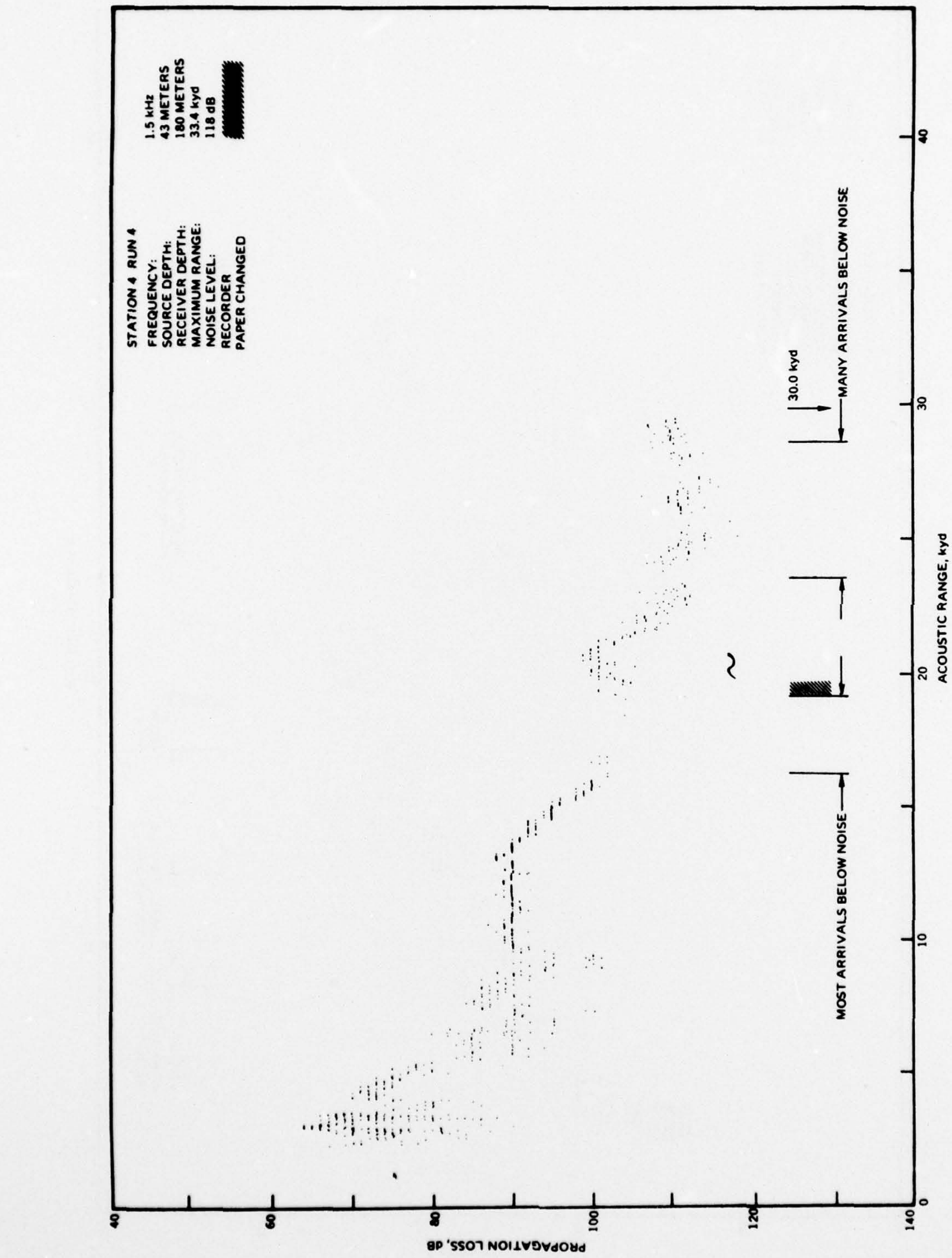
PROPAGATION LOSS VERSUS ACOUSTIC RANGE PLOTS

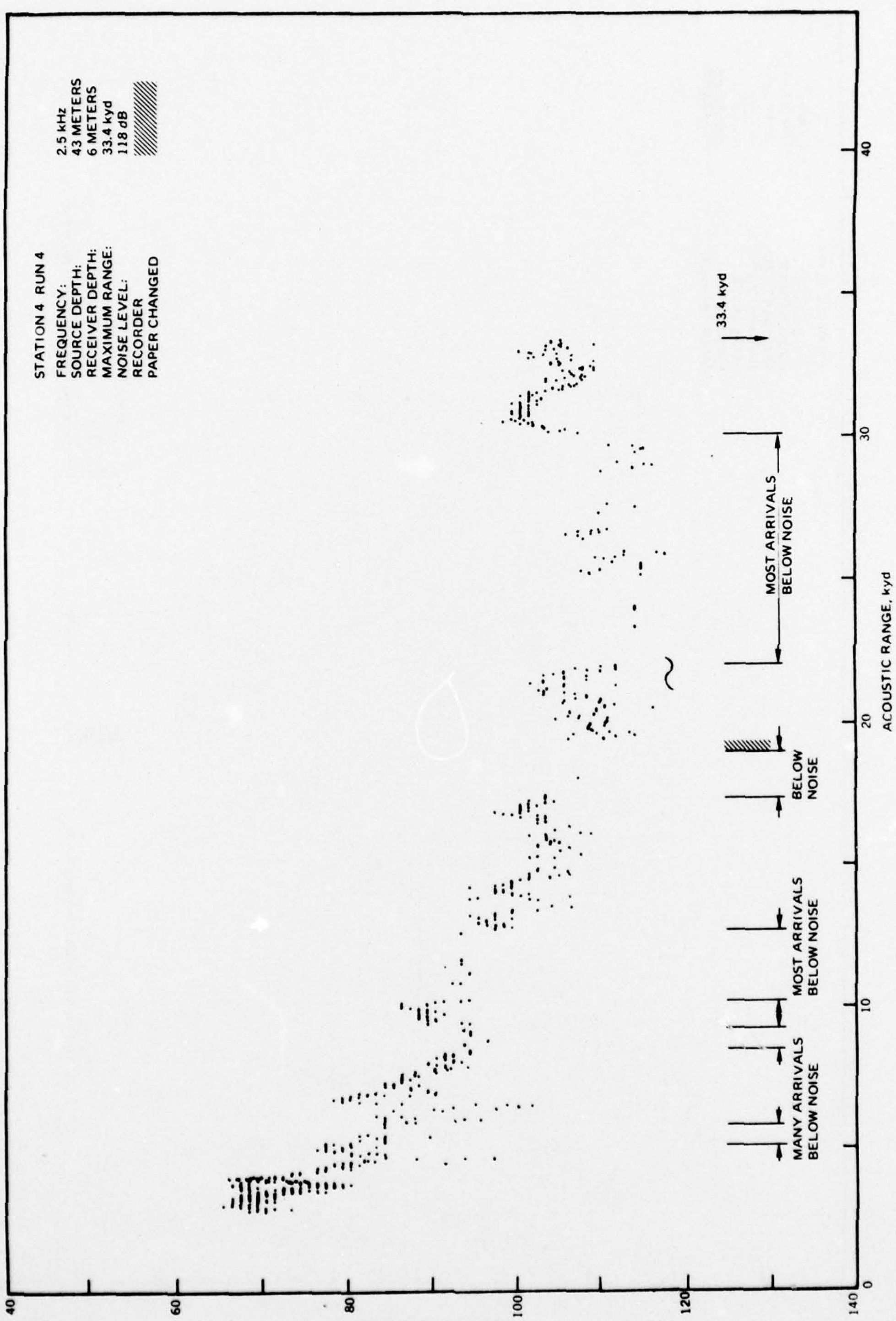

STATION 4 RUN 4
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL:
RECORDER PAPER CHANGED
NOT MEASURED
30.4 kyd
BELOW NOISE
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

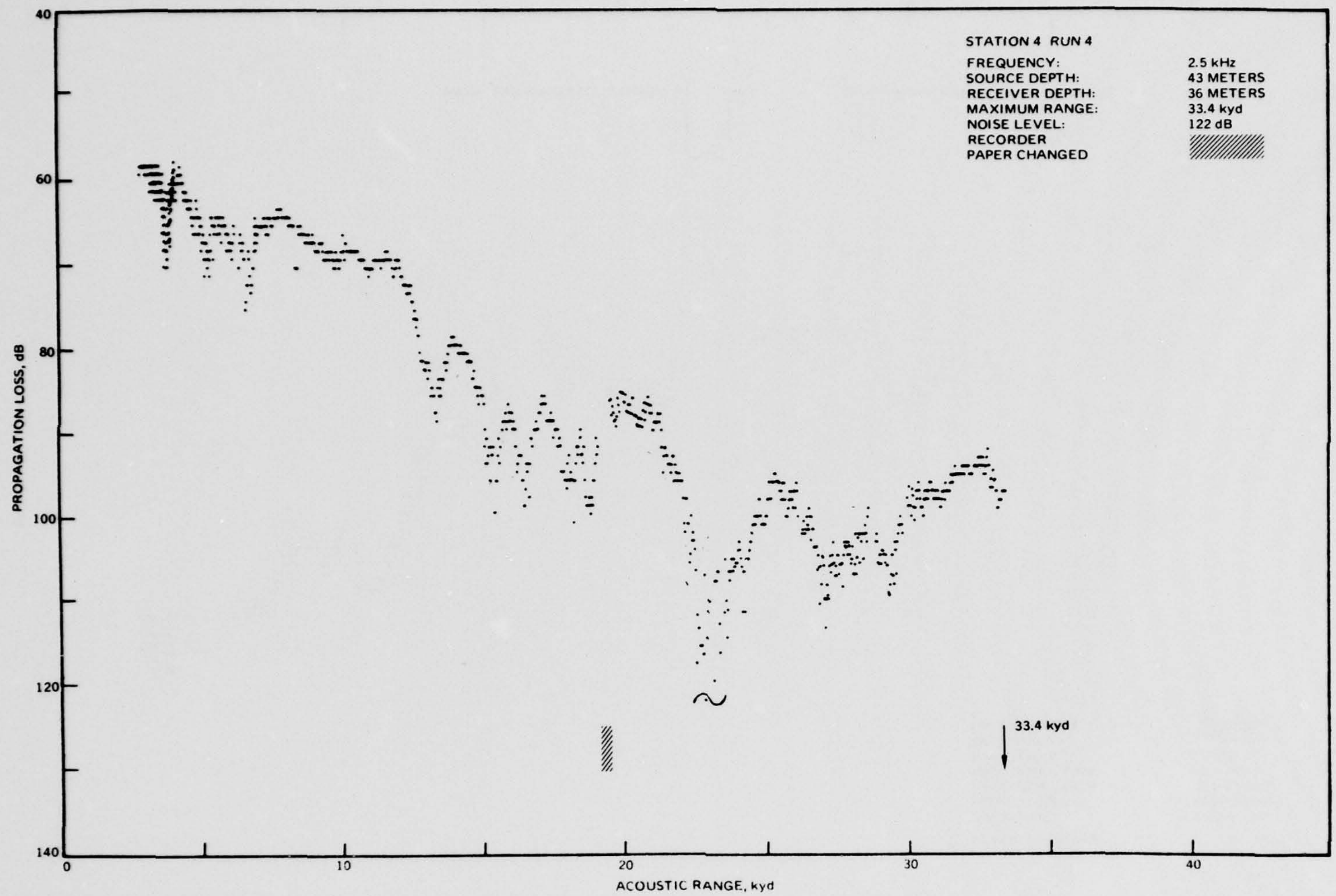

STATION 4 RUN 4
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 122 dB
RECORDER PAPER CHANGED
33.4 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
BELOW NOISE
ACOUSTIC RANGE, kyd
0
10
20
30
40
PROPAGATION LOSS, dB
40
60
80
100
120
140

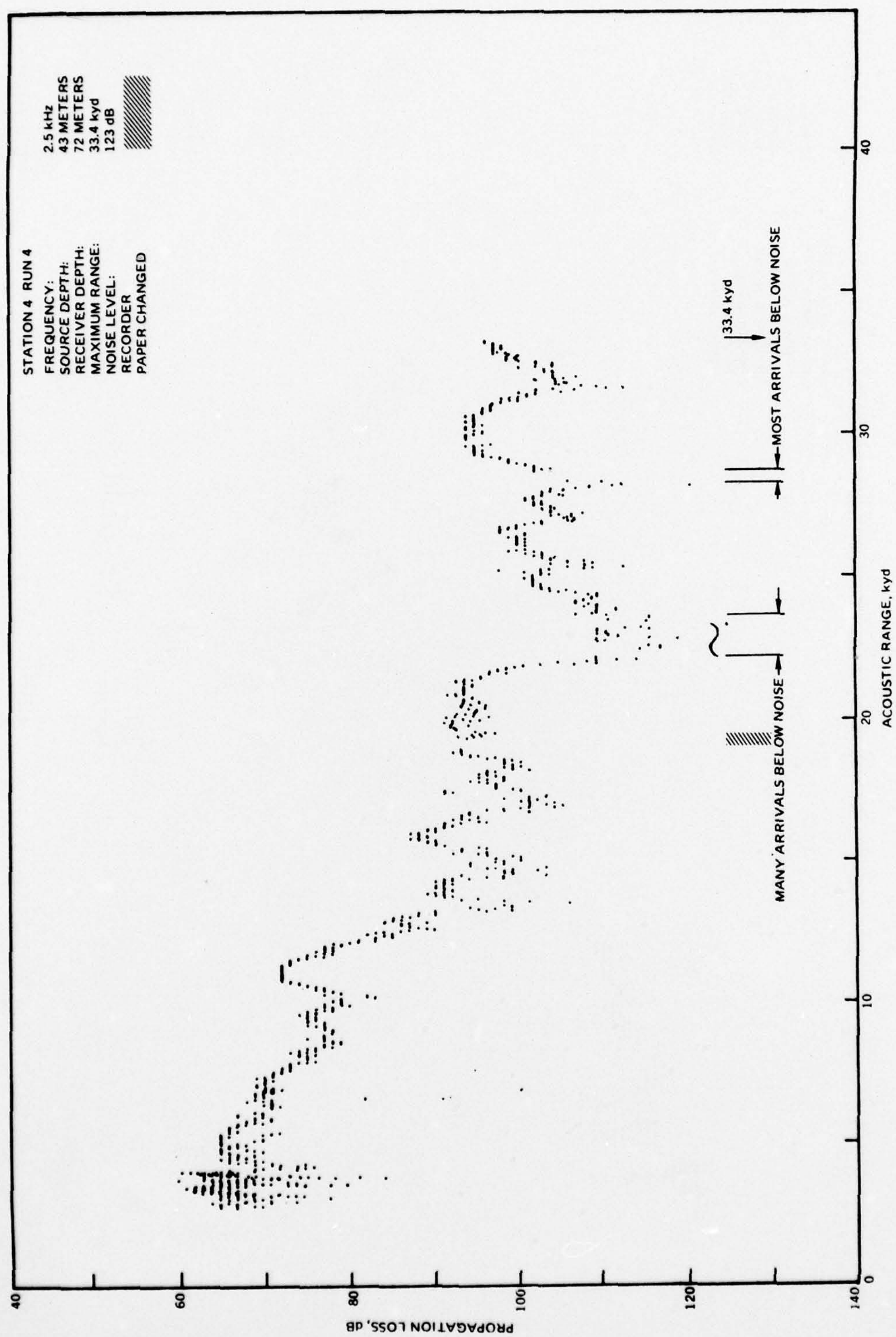

STATION 4 RUN 4
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 127 dB
RECORDER PAPER CHANGED
33.4 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

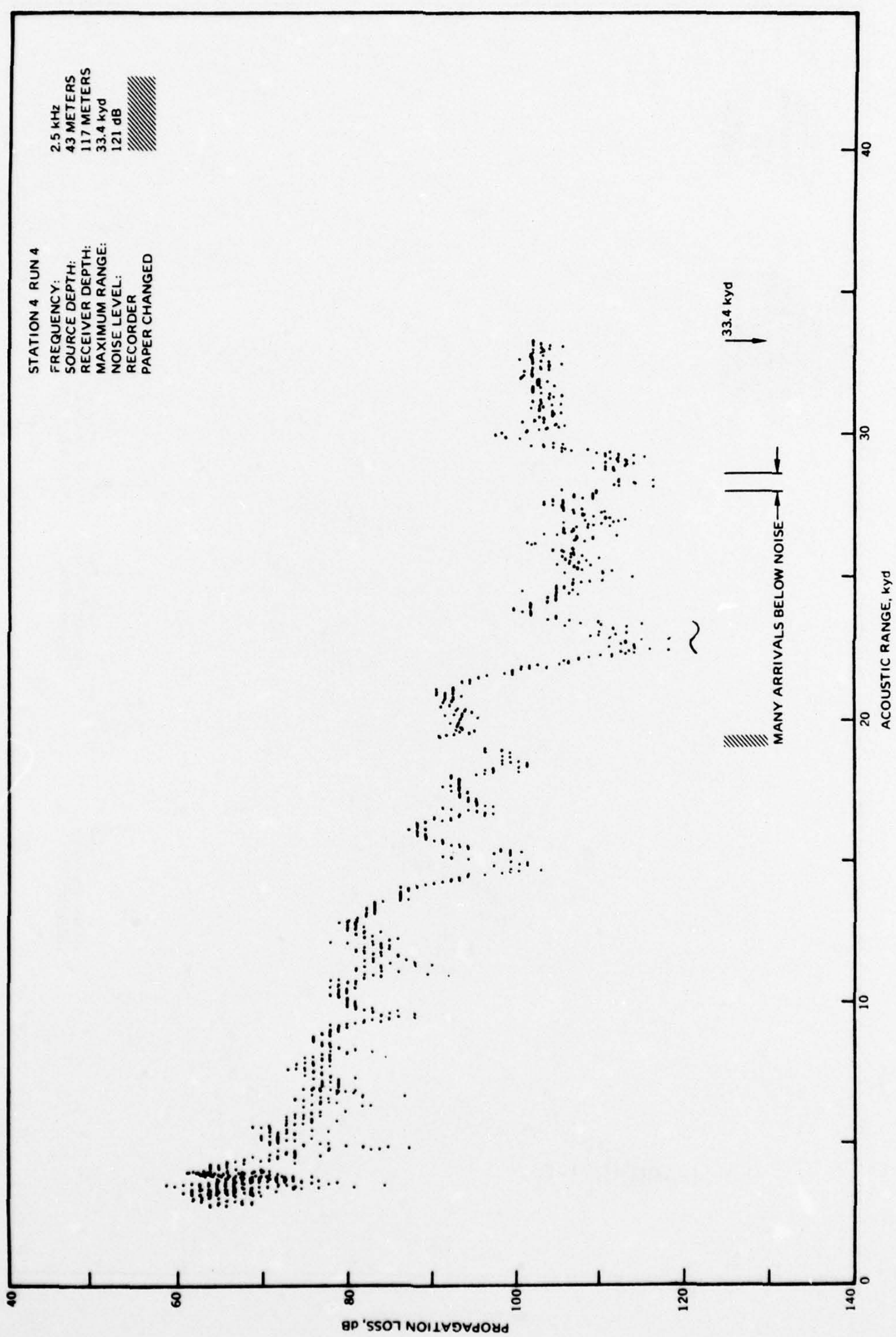

STATION 4 RUN 4
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 117 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 120 dB
RECORDER PAPER CHANGED
33.3 kyd
BELOW NOISE
MOST ARRIVALS BELOW NOISE
ACOUSTIC RANGE, kyd
PROPAGATION LOSS, dB
0
10
20
30
40
60
80
100
120
140

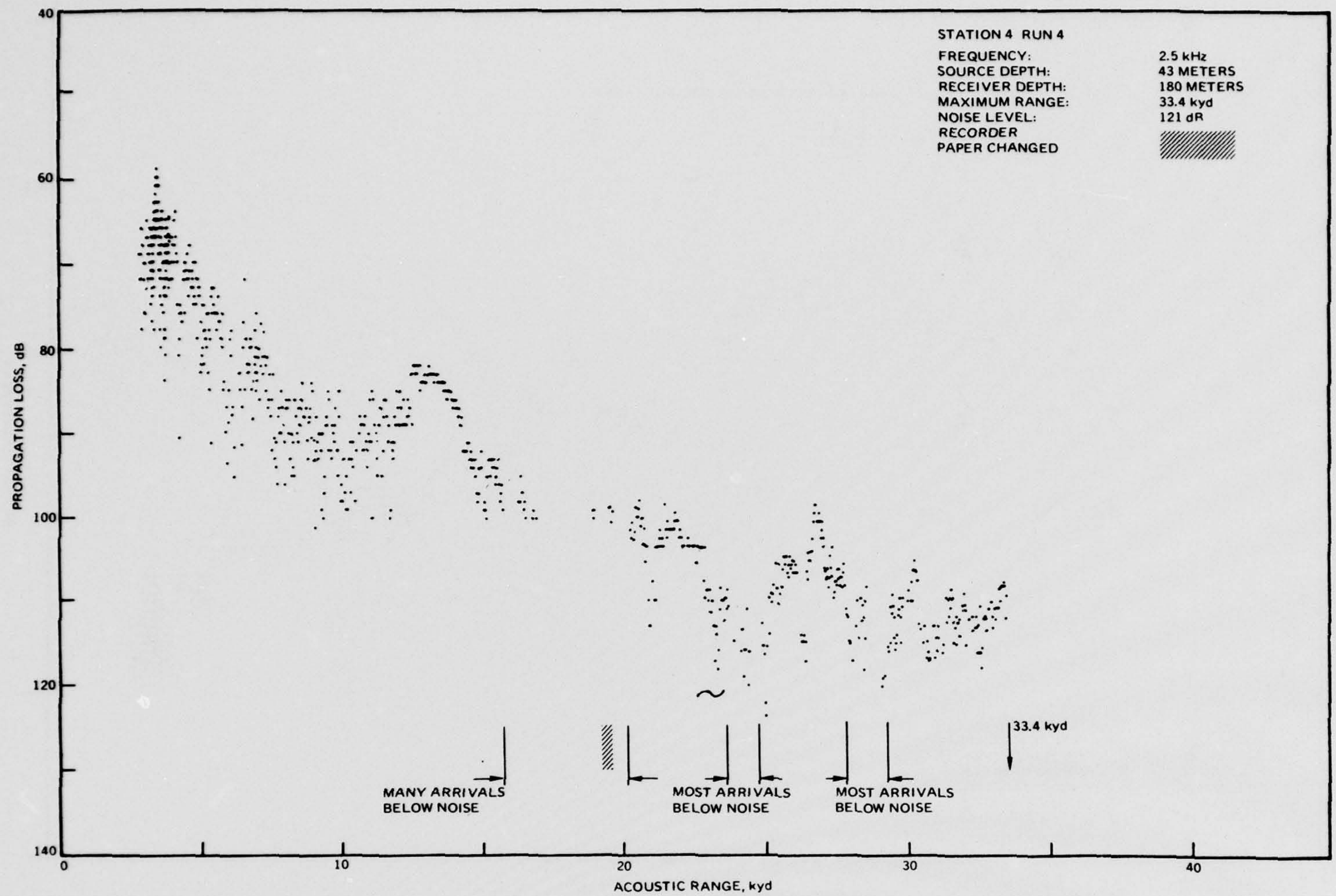

STATION 4 RUN 4
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 180 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 118 dB
RECORDER PAPER CHANGED
MOST ARRIVALS BELOW NOISE
MANY ARRIVALS BELOW NOISE
30.0 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 4 RUN 4
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 118 dB
RECORDER PAPER CHANGED
33.4 kyd
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
BELOW NOISE
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 4 RUN 4
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 122 dB
RECORDER
PAPER CHANGED
33.4 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 4 RUN 4
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 123 dB
RECORDER PAPER CHANGED
33.4 kyd
MOST ARRIVALS BELOW NOISE
MANY ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 4 RUN 4
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 117 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 121 dB
RECORDER PAPER CHANGED
33.4 kyd
MANY ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40


STATION 4 RUN 4
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 180 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 121 dB
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
33.4 kyd